AD-A126 110 PROCEEDINGS OF CONFERENCE ON LOCAL AREA MILITARY NETWORKS GRIFFISS AFB NEW YORK 28-30 SEPTEMBER 1982(U) ROME AIR DEVELOPMENT CENTER GRIFFISS AFB NY D B WARMUTH ET AL. 1982 1/6

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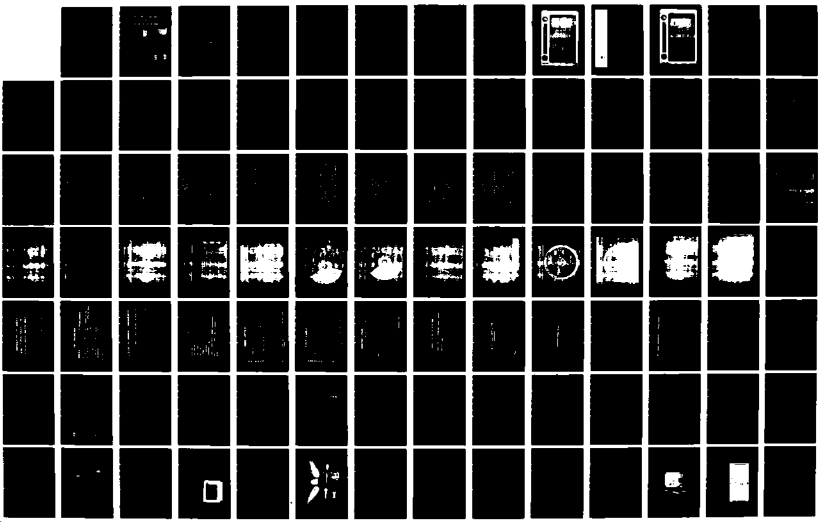
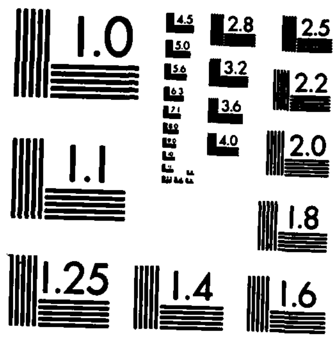


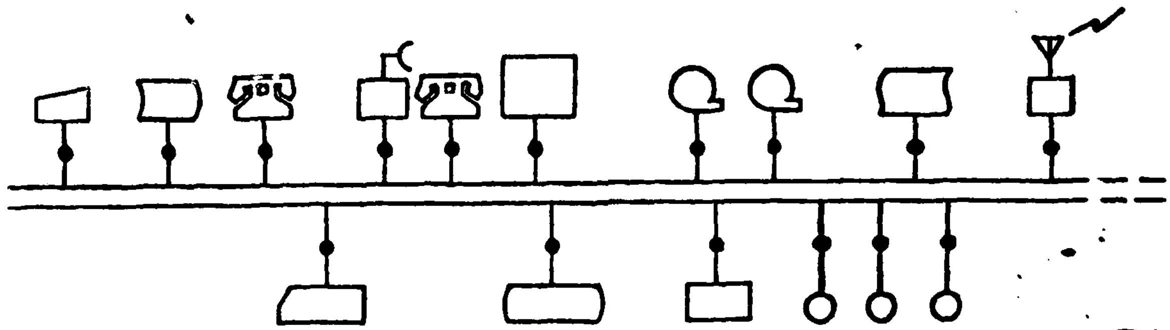


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(2)

PROCEEDINGS OF CONFERENCE
ON
LOCAL AREA MILITARY NETWORKS

ROME AIR DEVELOPMENT CENTER



GRIFFISS AFB, New York

28 - 30 SEPT, 1982

EDITED BY: DONALD B. WARMUTH & NEIL S. MARPLES

Approved for public release;

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LOCAL AREA MILITARY NETWORKS CONFERENCE

GRIFFISS AIR FORCE BASE, NY 28-30 SEPTEMBER 1982

AGENDA

27 SEP 82

1800-2000 Early Registration at the Officers Club

28 SEP 82

0800-0945 Registration at the Theater

0945-1000 Administrative Announcements

1000-1015 Welcome and Opening Remarks
By Col P. O. Bouchard
Commander, Rome Air Development Center

1015-1100 Keynote Address 5
By Charles C. Joyce
President, Network Strategies Inc.

1100-1230 Lunch

1230-1500 Local Area Network Requirements

Panel Chairman: Brig Gen John Paul Hyde - Commander, ECD and USAFE/DC 6

Panel Members:

Dr. Joel S. Lawson, Chief Scientist, C3I Systems and Technology Directorate, Naval Electronics Systems Command
Mr. Robert Puttcamp, US Army Communicative Technology Office, Ft Eustis VA 10
Lt Col Jonathan Katz, AFCC, Chief of Telecommunications Planning 25
Dr. Michael Muntner, President Contel Information Systems, Government Systems Division 35
Mr. Clifford O'Dell, Space Command 39

1500-1530 Break

28 SEP 1982 (Con't)

1530-1730 Technology I

1730 Adjourn

1830 Cocktails at the Beeches Restaurant

2000 AFCEA Dinner Meeting at the Beeches Restaurant
Dinner Speaker - Brig Gen John Paul Hyde
Commander, European Communications Division

29 SEP 82

0800-1000 Technology II

1000-1030 Break

29 SEP (Con't)

1030–1230 Local Network Issues

1230–1400 Lunch

1400–1545 Implementation I

1545–1600 Break

1600–1730 Implementation II

1730 Adjourn

30 SEP 82

0800-1000 Standardization

1000-1030 Break

1030-1230 Panel on Standardization

Panel Moderator: Mr.James L. Davis - RADC/DCLW

Panel Members:

Dr. Rona Stillman, USAF/ACD
Mr. John K. Summers, Mitre Corp
Mr. Dan Stokesberry, National Bureau of Standards
Mr. Steve Anderson, Sperry Univac

1230 Adjourn

BIOGRAPHY

Charles C. Joyce, Jr., President, Network Strategies Incorporated, Burke, Virginia. Mr. Joyce has extensive experience in data communications networks and information systems. He has directed a variety of projects including a study of Electronic Message System Policy for the U.S. Congress, and studies for government and commercial clients involving data communications network design, implementation and management. He teaches data communications seminars for Systems Technology Forum.

Prior to co-founding Network Strategies Incorporated, Mr. Joyce was Vice President of Richard L. Deal & Associates. Previously, he was Director of Information Technology and Policy at the MITRE Corporation, McLean, Virginia. He has also served as an Assistant Director in the Office of Telecommunications Policy, Executive Office of the President, and has exercised responsibility for planning, implementation, and review of communications and computer systems in the office of the Secretary of Defense and at the White House.

Mr. Joyce is active in the Armed Forces Communications and Electronics Association, and is a frequent speaker at technical conferences and seminars.

BIOGRAPHY

Brigader General John Paul Hyde is the Deputy Chief of Staff for Communications and Air Traffic Control, HQ United States Air Forces in Europe and Commander, US Air Force European Communications Division, both located at Ramstein Air Base, Germany. In these positions he is responsible for fixed and mobile telecommunications and air traffic-control systems throughout Europe and the Middle East for Air Force, US Government and other North Atlantic Treaty Organization and civilian agencies.

General Hyde was born July 21, 1934 in Cincinnati, Ohio. He earned a Bachelor of Science Degree from the University of Cincinnati in 1957 and both Master of Science and PhD degrees from the University of Pittsburg in 1963 and 1965 respectively, all in the field of electrical engineering.

After completing graduate school in 1965 he was assigned to the VELA Seismological Center, a division of the Air Force Technical Applications Center in Alexandria VA. In June 1969, General Hyde became Director of Aerospace-Mechanics Sciences Research at the Frank J. Seiler Laboratory, Air Force Systems Command, US Air Force Academy, Colorado.

General Hyde was the Associate Director of the Defense Communications Engineering Center, Reston VA in 1974. In February 1977, he was named Deputy Chief of Staff for Communications and Electronics, HQ Tactical Air Command, and Commander of the Tactical Communications Area, Langley AFB VA. He assumed his present duties in August 1980.

His military decorations and awards include the Department of Defense Superior Service Medal, Legion of Merit, Bronze Star Medal, Meritorious Service Medal, Air Force Outstanding Unit Award ribbon with "V" device and three oak leaf clusters, Republic of Vietnam Airmed Forces Honor Medal 1st Class and Republic of Vietnam Air Service Medal.

SPANGDAHLEM AIR BASE

- OPERATIONS: CAMPS, AFORMS
- LOGISTICS: MINET, ALCS, [illegible]
- SUPPLY/PERSONNEL: PHASE IV
- INTELLIGENCE: IITS
- WEATHER: EURMEDS
- CIVIL ENGINEER: USAFE CE NET
- COMPTROLLER: SMALL COMPUTER FOR [illegible]
- MEDICAL: CLINICAL ACCOUNTING
- ADMINISTRATION: "CREEK EDIT" WORD PRO[illegible]
- COMMUNICATIONS: ETS, SRT

EIFEL 1	GEADGE	JAMPS(AMHS)
EIFEL FOLLOW-ON	TRT	AWDS
AFIRMS	IITS	EDS
WWMCCS	SCARS	MINET
CAMPS	RAPS	IDHS
AFORMS	MDTS	CAFMS

- TERMINALS TIED TO UNIQUE SYSTEMS
- MIXTURE OF HARDWARE TYPES
- REDUNDANT REPORTING, MANNING

SPANGDAHLEM AIR BASE

- OPERATIONS: CAMPS, AFORMS
- LOGISTICS: MINET, ALCS, EDS
- SUPPLY/PERSONNEL: PHASE IV
- INTELLIGENCE: IITS
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- CIVIL ENGINEER: USAFE CE NET
- COMPTROLLER: SMALL COMPUTER FOR NE[illegible]
- MEDICAL: CLINICAL ACCOUNTING
- ADMINISTRATION: "CREEK EDIT" WORD PROCESSORS
- COMMUNICATIONS: ETS, SRT

V CORPS

DISPERSED COMMAND POST

TRADOC PAM 525-5

DNA

INTELL	INTELLIGENCE CELL
+ ASIC	ALL SOURCE INTELLIGENCE CENTER
CBC	CURRENT BATTLE CELL
PLANS	FUTURE BATTLE CELL
SPT	SUPPORT CELL
FSE	FIRE SUPPORT ELEMENT
CMD	COMMANDER, WHEN NOT AT TAC
ASOC	AIR SUPPORT OPERATIONS CENTER
RAOC	REAR AREA OPERATIONS CENTER
CAG	COMBAT AVAITION GROUP

STAFF PLANNING

AND

DECISION SUPPORT SYSTEM

SPADS

ACTO

DNA

CACDA

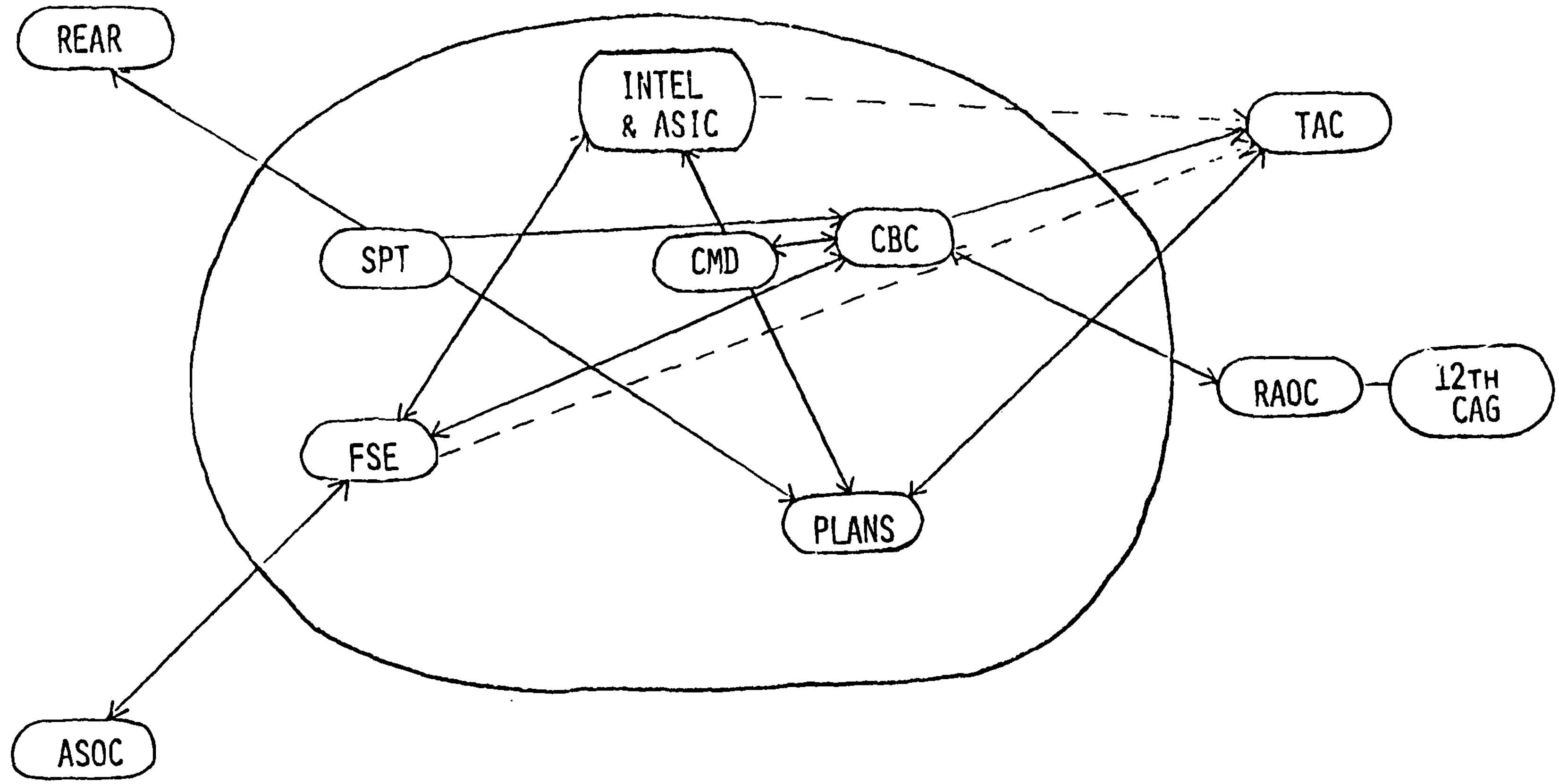
CATRADA

DARPA

FORSCOM

BDM

PERCEPTRONICS



CURRENT DISPERSED MODE
CONCEPT
V CORPS

EQUIPMENT LIST

APPLE II MICRO COMPUTER

CORVUS HARD DISK

VIDEO DISC PLAYER

SYMTEC PROFESSIONAL GRAPHICS SYSTEM

CORVUS OMNINET SYSTEM

PRINTERS

MODEMS

(PLOTTERS)

FLOPPY DISK DRIVES

EACH CELL WILL BE A LOCAL NETWORK ON THE CORVUS OMNINET SYSTEM

EACH CELL WILL HAVE:

- ONE OR MORE WORK STATIONS
- COMMUNICATIONS GATEWAY
  - ELECTRONIC MAIL
  - AUTOMATED MESSAGE DELIVERY
- PRINTER/PLOTTER GATEWAY
- HARD DISK GATEWAY
- ONE OR MORE VIDEO DISC PLAYERS

CRESTED EAGLE

G2

G3 OPS

ASIC

TAC CP

POWER PROBLEMS

AUTO TRANSFORMERS

3RD WIRE GROUND ON CONDUIT

V CORPS WILL RE-WIRE VANS

50 Hz NOT A PROBLEM

CARAVAN GUARD

MODULES HARDWIRED TOGETHER

CONNECTION TO OTHER MODULES THROUGH
TASS NETWORK

MAY TRY DBP FOR UNCLASSIFIED
COMMUNICATIONS

NOT SURE AT THIS TIME HOW MUCH EQUIPMENT WILL BE AVAILABLE FOR CARAVAN GUARD

VIDEO DISC WILL NOT BE READY

VIDEO DISC WILL BE USED IN REFORGER 82 FOR FIRST TIME

V CORPS VANS WILL BE REWIRED FOR CARAVAN GUARD

REFORGER 82

8ID ACTIVE WITH DISPERSED DTOC

MODULE TO MODULE COMMUNICATION WITH
V CORPS

V CORPS MAINLY AS UMPIRES

ABLE ARCHER 82

WIDER DISPLERSION FOR BOTH V CORPS
AND 8ID

COMMUNICATIONS OVER TASS NETWORK

UNCLASSIFIED OVER DBP

MESSAGE CENTER DISPERSED

WINTEX - 83

FULLY DISPERSED TEST

V CORPS

8 ID

MAY TRY SOME COMMUNICATION WITH
VII CORPS DISPERSED CP

POST WINTEX - 82

TESTS AS NECESSARY TO INSURE WE HAVE A WORKING SYSTEM

INTEGRATION WITH VII CORPS

INTEGRATION WITH XVIII AIRBORN CORPS

AIR FORCE
BASE LEVEL
NETWORKING REQUIREMENTS

HQ AFCC/XODX
27 SEP 82

2 14171 ACC

BASE LEVEL NETWORKING
MENU

- BASE TELECOMMUNICATIONS SYSTEM (BTS)
  - -- CURRENT ENVIRONMENT AND PROBLEM AREAS
  - -- ACTIONS UNDERWAY
- FUTURE NEEDS
  - -- QUANTITATIVE
  - -- QUALITATIVE
- ISSUES
  - -- INFORMATION ARCHITECTURE
  - -- INTEGRATION
  - -- STANDARDS
- AFCC STATEMENT OF NEED:
  - -- BASE LEVEL INFORMATION TRANSMISSION SYSTEM

2 14172 ACC

BASE LEVEL NETWORKING
CURRENT PROGRAMS

- TELEPHONE
  - SCOPE DIAL: REPLACE GOVERNMENT-OWNED SWITCHES
  - EUROPEAN TELEPHONE SYSTEM: MODERNIZE SWITCHES IN EUROPE
  - SCOPE EXCHANGE: REPLACE LEASED SWITCHES
- TELECOMM CENTERS
  - STANDARD REMOTE TERMINAL (SRT)
  - AIR FORCE AUTOMATED MESSAGE PROCESSING EQUIPMENT (AFAMPE)
- ADP - PHASE IV CAPITAL REPLACEMENT
- INTRA-BASE RADIO-VOICE PRIVACY
- ALARMS & SENSORS - COMPUTER DRIVEN SYSTEMS
- FACSIMILE/TELECONFERENCE: STANDARD FACSIMILE

2 14173 ACC

BASE LEVEL NETWORKING
BASE TELECOMMUNICATIONS SYSTEM
PRIMARY SUBSYSTEMS

- BASE WIRE AND TELEPHONE SWITCHING SYSTEM
  - -- CENTRAL SWITCH
  - -- CABLE PLANT
- TELECOMMUNICATIONS CENTERS
  - -- AUTODIN TERMINAL
  - -- ANCILLARY PROCESSING
- BASE ADP AND REMOTES
  - -- B3500/B3700/UNIVAC 1050-II
- INTRA-BASE RADIO (IBR)
  - -- INDIVIDUAL NETS
- ALARM AND SENSOR SYSTEMS
- OTHER SYSTEMS-FACSIMILE, CCTV, TELECONFERENCING, SECURE VOICE.

2 14174 ACC

BASE LEVEL NETWORKING
BASE TELECOMMUNICATIONS SYSTEM
PROBLEMS

- ACCELERATING DEMANDS
- SYSTEM/SUBSYSTEM/HARDWARE PROLIFERATION
- COMPLEX INTERFACES
- TRANSMISSION PLANT OBSOLESENCE
- LOGISTIC SUPPORT
- NEED FLEXIBILITY
- CANNOT AFFORD DEDICATED OVERLAYS

2 14175 ACC

BASE LEVEL NETWORKING
WHERE WE'RE AT

- MODERNIZATION DRIVEN BY LOGISTICS AND MANPOWER CONSIDERATIONS
- MOSTLY A ONE-FOR-ONE REPLACEMENT
- SYSTEM APPROACH REQUIRED
- BASIC TRANSMISSION SYSTEM NOT ADDRESSED
- LOCAL AND WIDE AREA NETWORKING & CONCEPTS
  - -- PROVIDE IMPROVED TRANSMISSION AND SERVICES
  - -- APPROACH UBIQUITOUS SERVICE

2 14176 ACC

BASE LEVEL NETWORKING
QUANTITATIVE REQUIREMENTS

- RESOURCE GROWTH
  - -- TERMINAL DEVICE EXPLOSION: PROJECTED OVER 110,000 BY 1989
  - -- INTRODUCTION OF "OFFICE AUTOMATION", PERSONAL MICRO-COMPUTERS AND WORK STATIONS
  - -- FUNCTIONAL MANAGEMENT INFORMATION/DATA PROCESSING SYSTEMS
- CAPACITY LIMITATIONS
  - -- CURRENT BASE PLANTS SIZED FOR VOICE AND LIMITED DATA
  - -- CABLE PLANTS ENGINEERED FOR ANALOG VOICE - LIMITED BANDWIDTH

2 14177 ACC

BASE LEVEL NETWORKING
QUALITATIVE REQUIREMENTS

- IMPROVED CONNECTIVITY
  - CONNECTION ORIENTED AND "CONNECTIONLESS"
  - TERMINAL-TO-TERMINAL AND TERMINAL TO HOST
- HANDLE INFORMATION TYPES: DATA, IMAGERY, VIDEO, SECURE VOICE, FACSIMILE
- IMPROVED SERVICES-HANDLE DATA ORIENTED PROTOCOLS
- IMPROVED TRANSMISSION QUALITY-END-TO-END TRANSPORT INTEGRITY
- FLEXIBILITY: RELOCATION, RESTORAL, INTERFACE, INTEGRATION
- ECONOMICAL GROWTH
- SYSTEM/NETWORK MANAGEMENT AND CONTROL

2 14178 ACC

BASE LEVEL NETWORKING
ISSUES

- INFORMATION ARCHITECTURES
  -- DISTRIBUTION OF RESOURCES
  -- PROCESSING VS COMMUNICATING
  -- CHANGING ORGANIZATIONAL/FUNCTIONAL BOUNDRIES
- INTEGRATION
  -- VERTICAL AND HORIZONTAL
  -- TECHNICAL-GATEWAYS
    --- INTERFACE WITH EXISTING SUBSYSTEMS
    --- INTERFACE WITH EMERGING SYSTEMS
- STANDARDS
  -- CHOOSE NOW
  -- WAIT FOR ADOPTION

2 14179 ACC

BASE LEVEL NETWORKING
AFCC STATEMENT OF NEED (SON)
MODERNIZING THE BASE LEVEL INFORMATION TRANSMISSION SYSTEM

- PURPOSE: ESTABLISH A PROGRAM TO DESIGN, ACQUIRE, INSTALL, MANAGE, OPERATE AND MAINTAIN AN INTEGRATED INFORMATION HIGHWAY SYSTEM ON MOST AIR FORCE BASES
- SATISFY REQUIREMENTS
- MAKE PRUDENT CAPITAL INVESTMENTS AND RESOURCE REALLOCATIONS
- EXPLOIT LOCAL AREA NETWORKING CONCEPTS AND TECHNOLOGIES
- ESTABLISH AIR FORCE CORPORATE APPROACH TO INFORMATION TRANSPORTATION

2 14188 ACC

OPERATIONAL LAN IMPLICATIONS

- INCREASE AVAILABILITY/MAINTAINABILITY
- MONITOR PERFORMANCE/DETECT PROBLEMS
- NEW SOFTWARE RELEASES
- RAM RESIDENT CODE
- RELIABLE NETWORK CONTROL CENTER (DLL/ULD)
- NETWORK ORGANIZATIONAL RESPONSIBILITY
  - OPERATE (INTEGRATE WITH TECH CONTROL)
  - ACCESS CONTROL (SECURITY OFFICE)
  - ADMINISTER (CONFIGURATION CONTROL)

REQUIREMENTS TRENDS (NON-OFFICE ENVIRONMENT)

- CABLE USE FOR MULTIPLE SERVICES
- HIGHER INTERFACE SPEEDS
- GATEWAYS TO OTHER NETWORKS
- FUNCTIONAL EXPANDIBILITY (NEW INTERFACES, SPEEDS, SERVICES)
- NOT A TOY!!

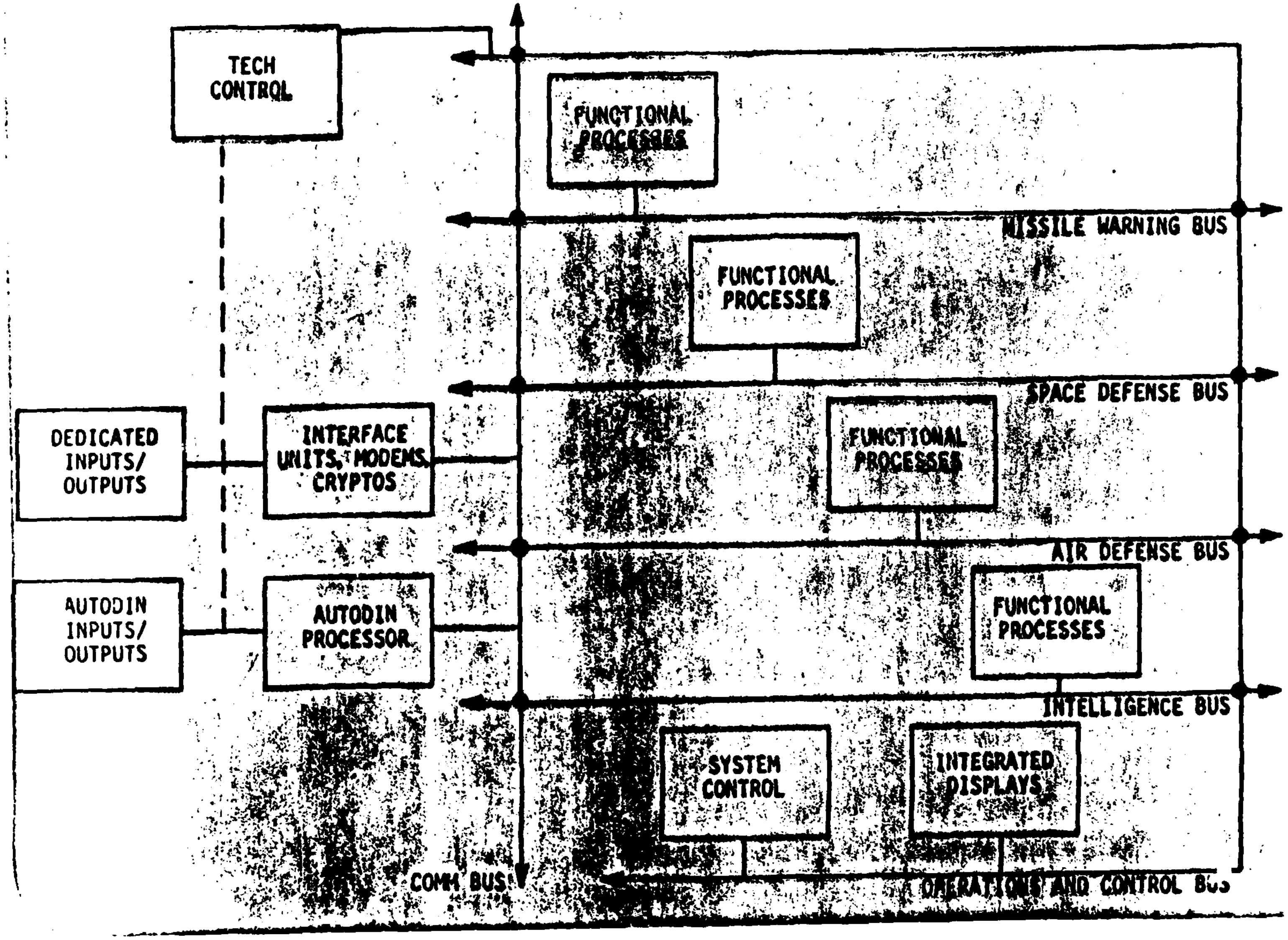
LAN APPLICATIONS

- OFFICE VS DATA PROCESSING VS PROCESS CONTROL
- COPPER REPLACEMENT
  - N TO 1 (MUX, STAT MUX)
  - N TO N (CLASSICAL NETWORK)
- DISTRIBUTED "MESSAGE" SWITCH
  - ROUTE TRAFFIC: SOURCE TO DESTINATION
  - FLOW CONTROL
  - ACCESS/SECURITY CONTROL
  - PERFORMANCE MONITORING & AUDIT TRAILS
  - DATA CONTENT ROUTING
- DISTRIBUTED FRONT END
  - OFF-LOAD COMM PROCESSING TO LAN
  - ACCESS TO GATEWAYS

LOCAL AREA NETWORK (LAN)

REQUIREMENTS & IMPLICATIONS

CONCEPTUAL APPLICATION OF SELECTED ARCHITECTURE



SUMMARY

ADP ARCHITECTURE WILL SATISFY THE EVOLVING NORAD MISSIONS

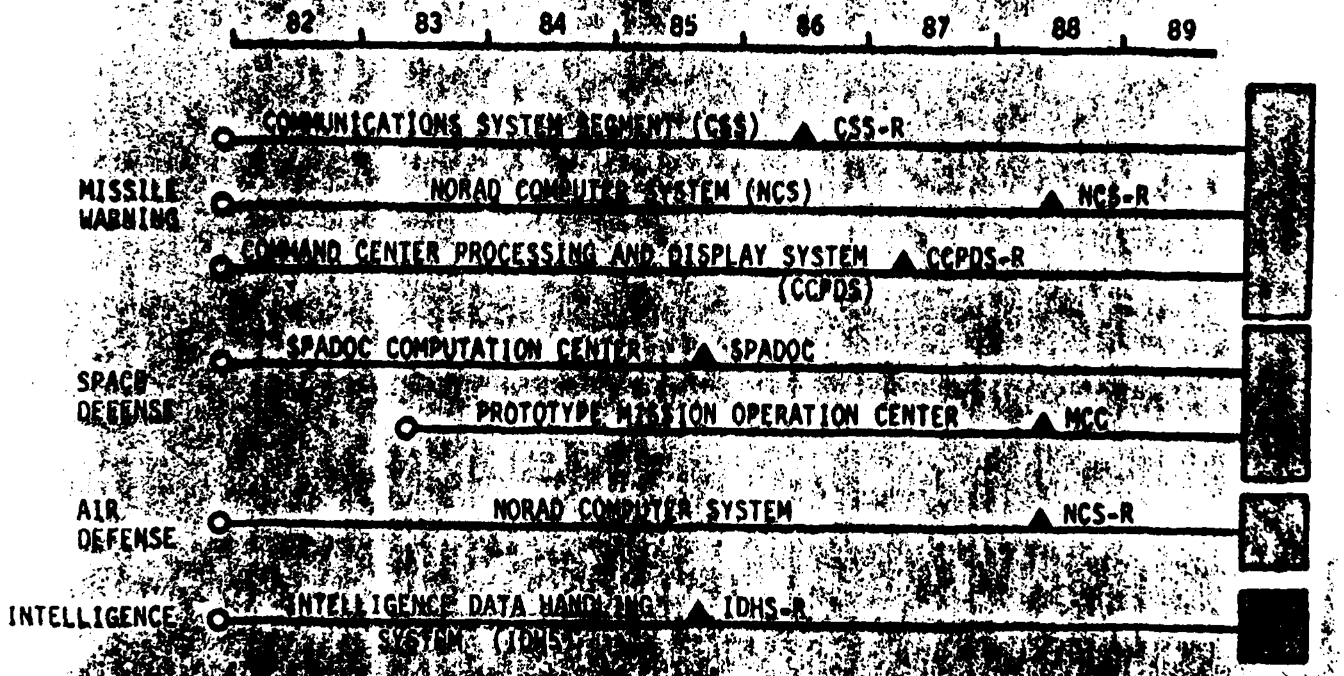
TECHNICAL INTERCHANGE

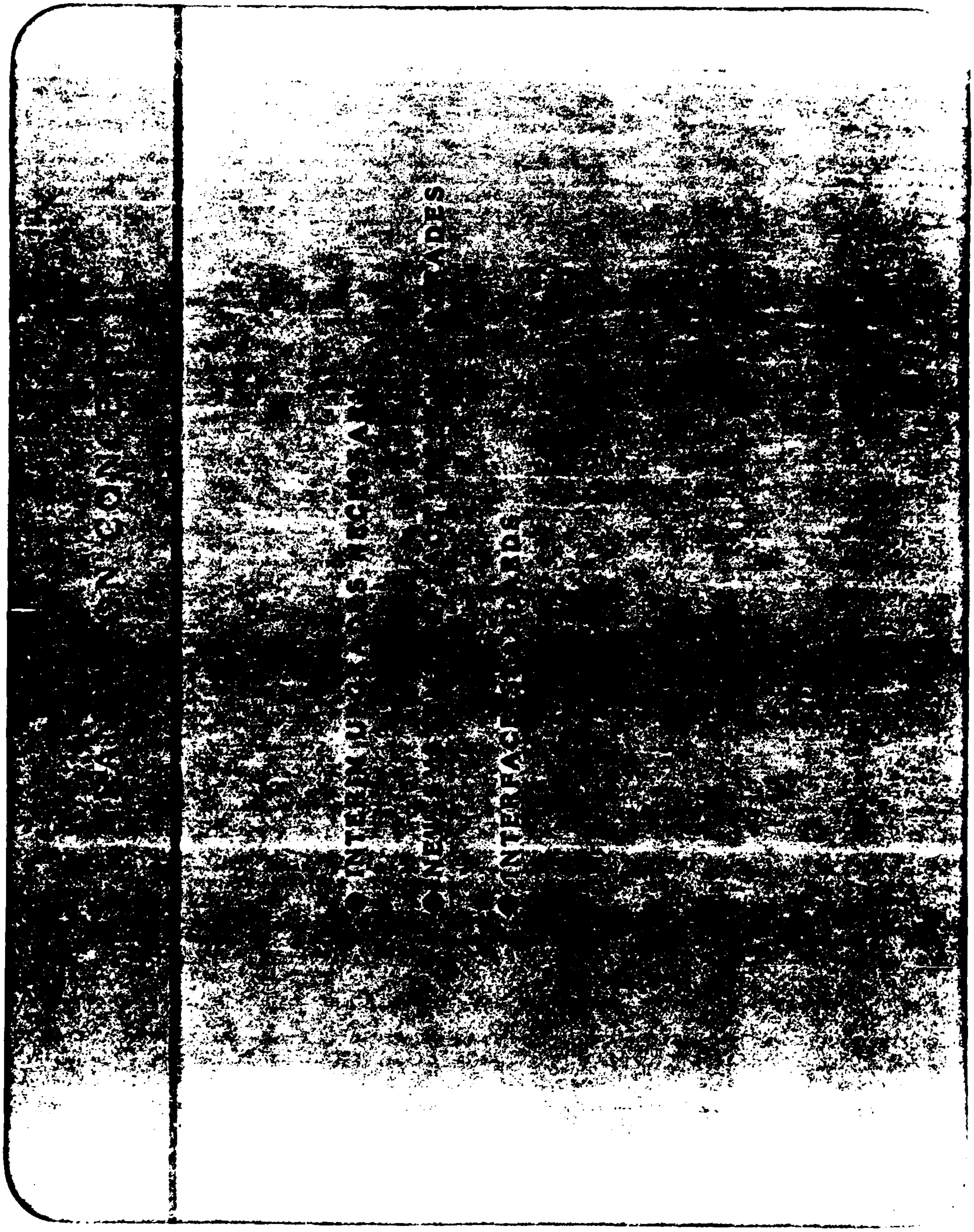
ADVANCED INFORMATION AND DECISION SYSTEM	HARRIS CORPORATION
BETAC CORPORATION	HARVARD UNIVERSITY
BOLT BERANEK AND NEWMAN, INC.	HONEYWELL INCORPORATED
BURROUGHS CORPORATION	INTERNATIONAL TELEPHONE AND TELEGRAPH
CARNEGIE-MELLON UNIVERSITY	MARTIN-MARIETTA AEROSPACE
COMPUTER CORPORATION OF AMERICA	MITRE CORPORATION
CONTROL DATA CORPORATION	NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
DIGITAL COMMUNICATIONS CORPORATION	NETWORK SYSTEMS CORPORATION
FORD AEROSPACE COMMUNICATIONS CORPORATION	ROME AIR DEVELOPMENT CENTER
GENERAL DYNAMICS	STATE UNIVERSITY OF NEW YORK AT BUFFALO
GENERAL ELECTRIC	UNIVERSITY OF MICHIGAN

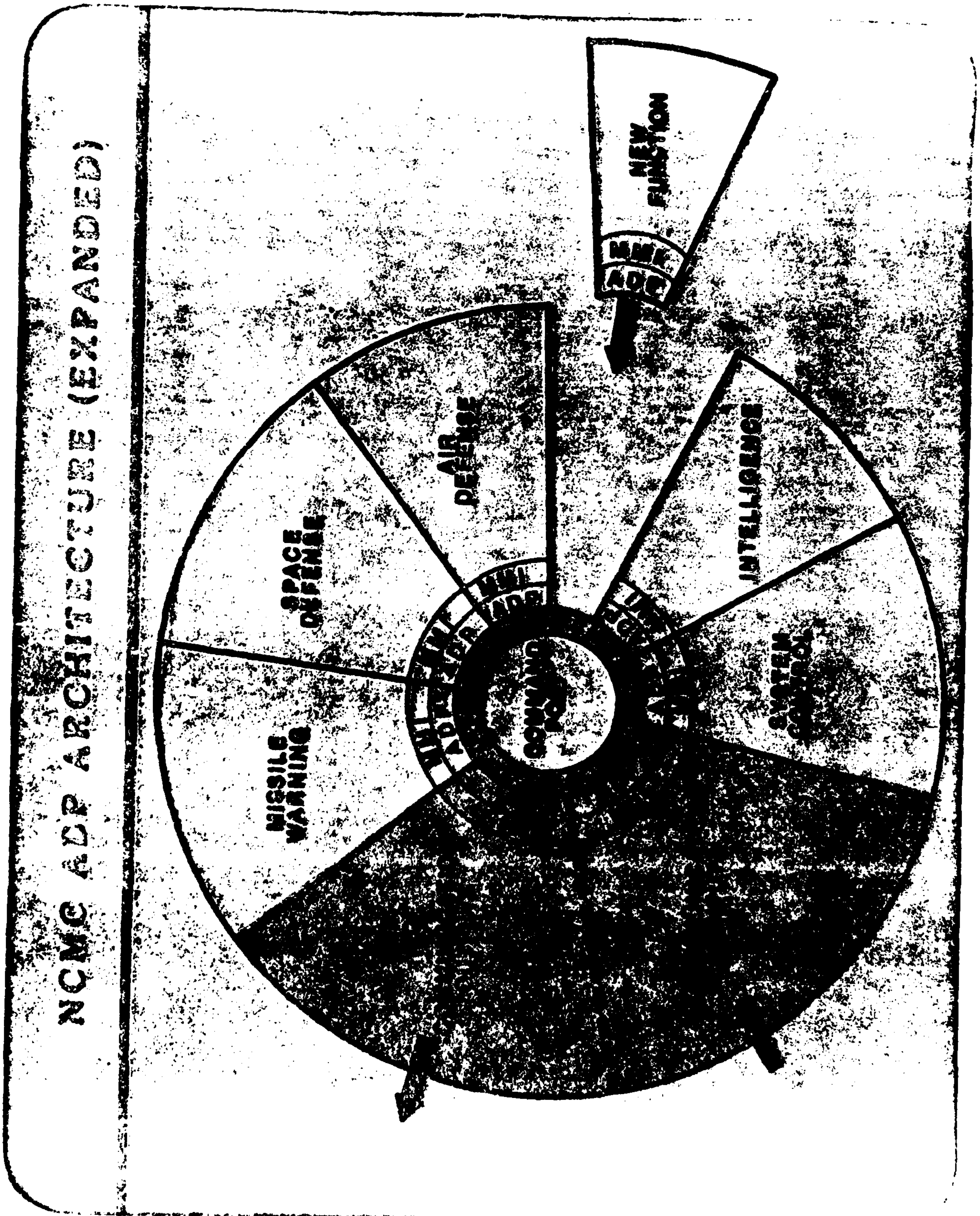
SUMMARY

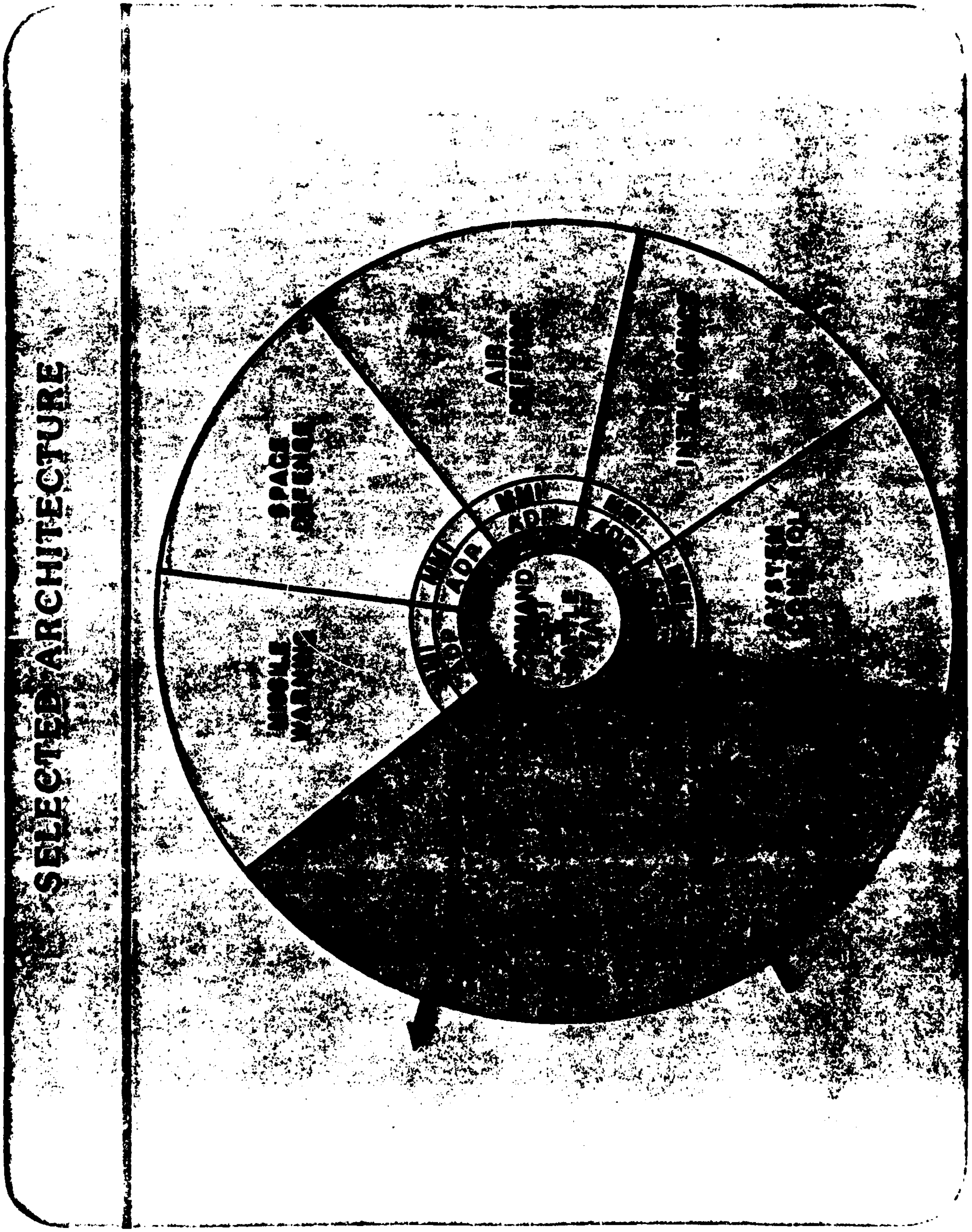
ADP ARCHITECTURE WILL SATISFY THE EVOLVING NORAD MISSION

TRANSITION SCHEDULE






NCMC ADP ARCHITECTURE (EXPANDED)
MISSILE WARNING
SPACE DEFENSE
AIR DEFENSE
INTELLIGENCE
NEW FUNCTION
MMI
ADP


SELECTED ARCHITECTURE
SPACE DEFENSE
AIR DEFENSE
MISSILE WARNING
SYSTEM CONTROL
ADP
MMI

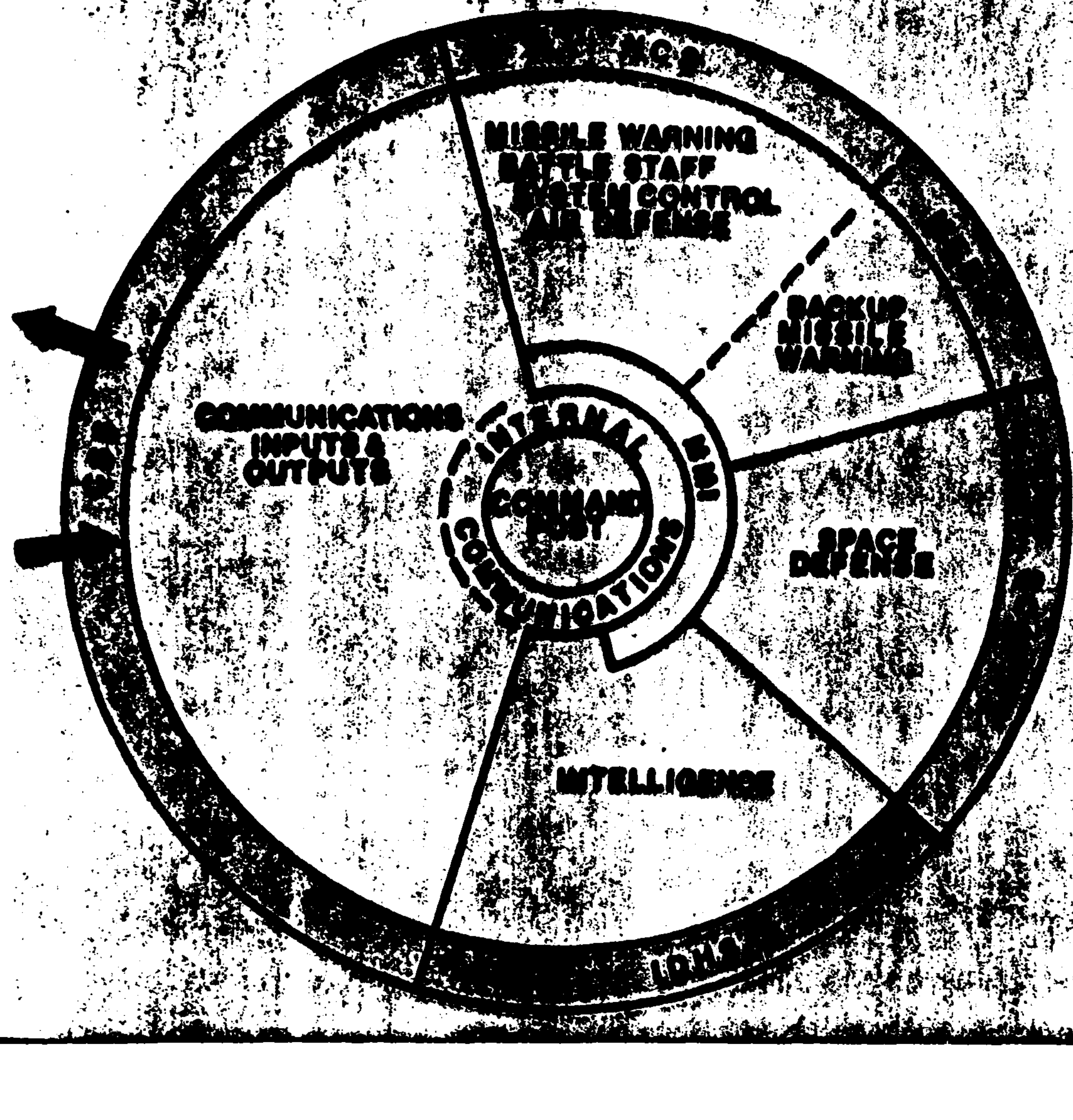
FEATURES OF SELECTED ARCHITECTURE

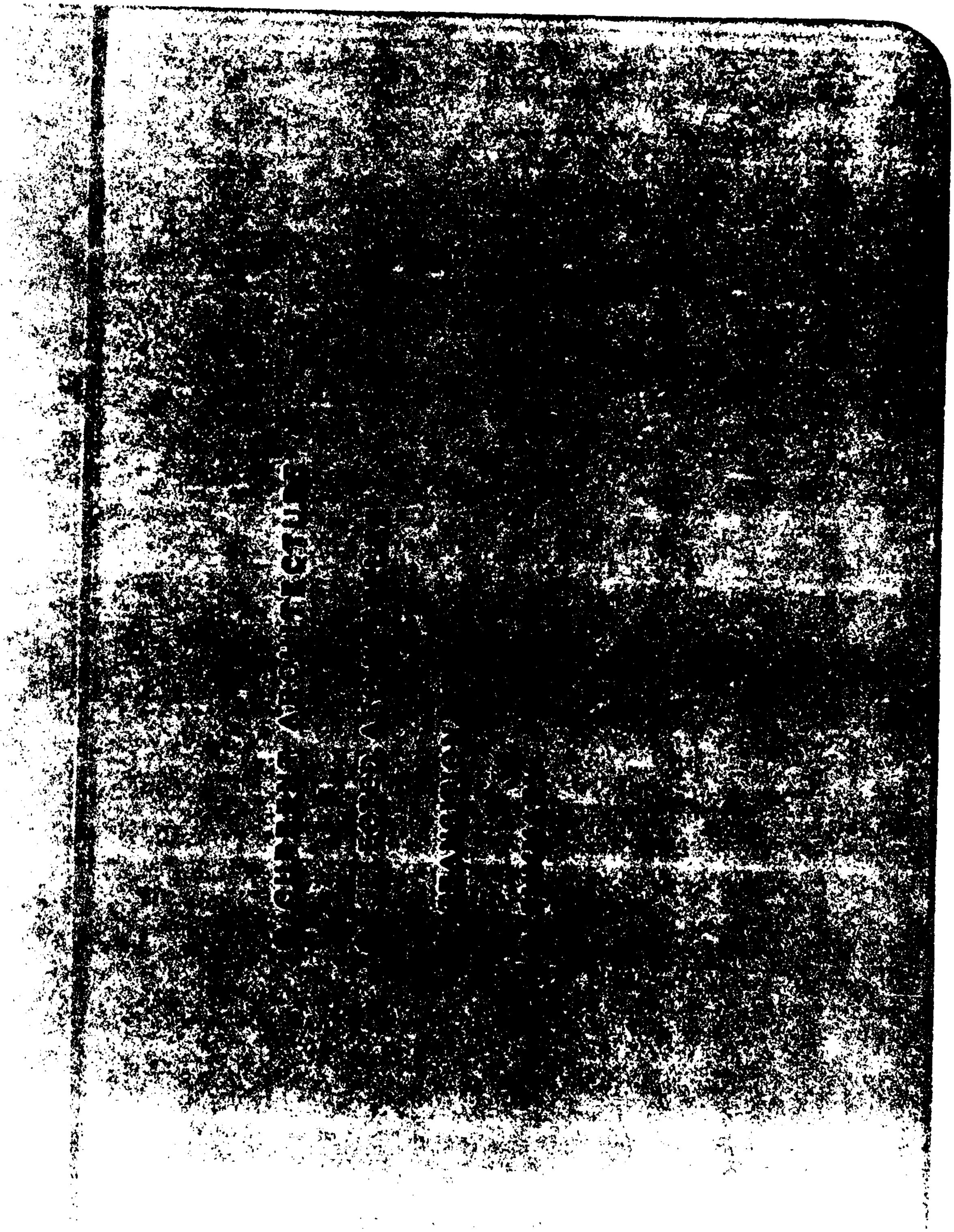
- SEPARATION OF MISSIONS
- CAN BE UPGRADED
- FLEXIBLE
- INTERFACE STANDARDS WILL BE APPLIED

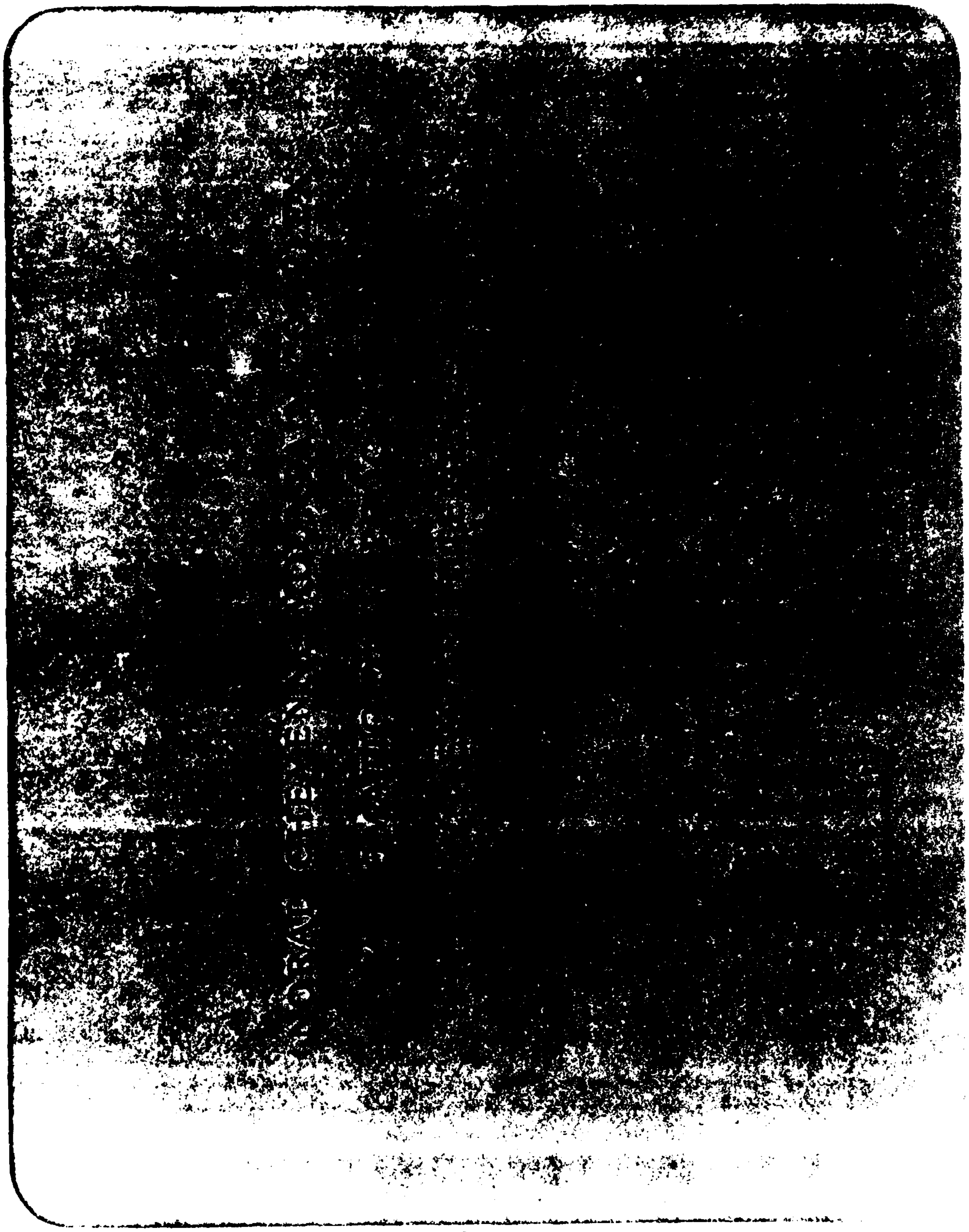
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- CHANGES INCREASE [illegible]

-48-

CURRENT NCMC ARCHITECTURE







Technolgy I (1530-1730 28 Sep)

Session Chairman: Lt Mark McCall - RADC/COTE

"Comparison of Coaxial Cable and Fiber Optics for Local Area Networks," Mr. Tom Reale and Mr. Charles Husbands, MITRE Bedford Operations

The technolgy for broadband local area networks has advanced rapidly over the last several years. Previous networks were constructed entirely of coaxial cable with fiber optics for point-to-point links. Recently hybrid systems are being designed and implemented. It is envisioned that as fiber optic technology progresses it will usurp coaxial cable as the communication medium. This paper will address some issues involved in the transition with particular emphasis on topology and protocol.

"Multi Loop Fiber Network," Mr. Gerd Keiser and Mr. Raynor W. Taylor, GTE Systems, Communications Systems Division

A network using five full duplex optical fiber loops is being developed for local area data transmission. Each pair in a loop can maintain an effective data rate of 20 Mbs in opposite directions, thus giving a total system capacity of 200 Mbs. Each node is three simultaneous active network connections and supports up to 10 variable speed users. The nodes provide real-time actions and flow control while a network control center handles failures, monitors system performance, and provides long term management and network optimization.

"Fiber optic Data Bus Technology and Applications," Mr. David R. Porter, ITT Electro-Optical Products Division

Fiber Optics technology has rapidly matured to a point where practical fiber optic data bus systems are now being demonstrated. Two systems will be described: (1) 1 Mbs MIL-STD 1553 compatible fiber optic bus and (2) 100 Mbs fiber optic bus. System function, architecture, key technological developments, performance and bus access protocol will be addressed.

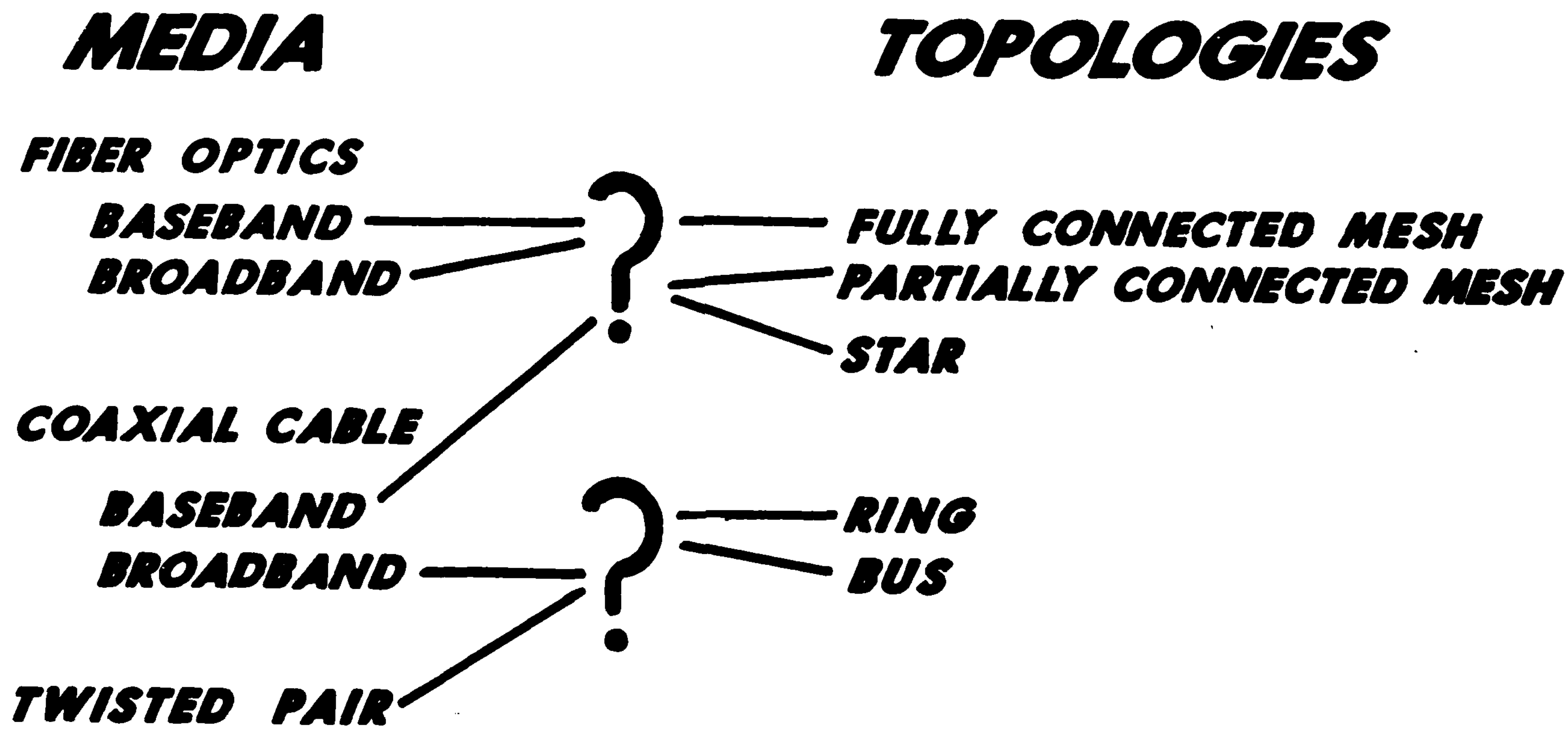
"Teleconferencing Fiber Optic Communication System," Mr. Ralph Mednick and Mr. Raynor W. Taylor, GTE Systems, Communications Systems Division

GTE has developed a wideband local area network system that provides full motion video conferencing, other voice, data, video, and audio services to military or civilian users. The system is a star network optic subscriber loop carrying all traffic. As many as 25 separate user locations can be connected in a single video conference; several conferences may take place simultaneously. Full screen video or split screen picture presentation as well as graphic modes are available. Other features of the system will be described as well.

COMPARISON OF MEDIA AND TOPOLOGIES FOR LOCAL AREA NETWORKS

C. HUSBANDS
T. J. REALE
THE MITRE CORPORATION

THE PROBLEM


MEDIA
TOPOLOGIES
FIBER OPTICS
BASEBAND
BROADBAND
COAXIAL CABLE
BASEBAND
BROADBAND
TWISTED PAIR
?
?
FULLY CONNECTED MESH
PARTIALLY CONNECTED MESH
STAR
RING
BUS

CLASSICAL MEDIA COMPARISON

	FIBER OPTICS		COAXIAL CABLE		TWISTED PAIR
	BROADBAND	BASEBAND	BROADBAND	BASEBAND	
AVAILABLE BANDWIDTH	30MHZ-300MHZ	1GHZ	450 MHZ	20MHZ-50MHZ	10MHZ
NO OF CARRIERS (VIDEO)	4 - 10	1	50	1	1
MAXIMUM SINGLE CHANNEL DATA RATE	5-10 MBPS	300 MHZ	5-10 MBPS	50MBPS	10MBPS
ERROR RATE (UNCORRECTED)	10^{-12}	10^{-12}	10^{-12}	10^{-12}	10^{-10}
SPACING BETWEEN TAPS	0	0	0	2 M	1 M
NO OF INSTALLED SYSTEMS	NO LAN's 10 POINT TO POINT	$>10^2$	10^4	10^2	10^4

LAN FACTORS

AVAILABILITY

MAITAINABILITY

SURVIVABILITY

FAIL SOFT

CONNECTIVITY

EXPANDABILITY

TRANSFER TIMES

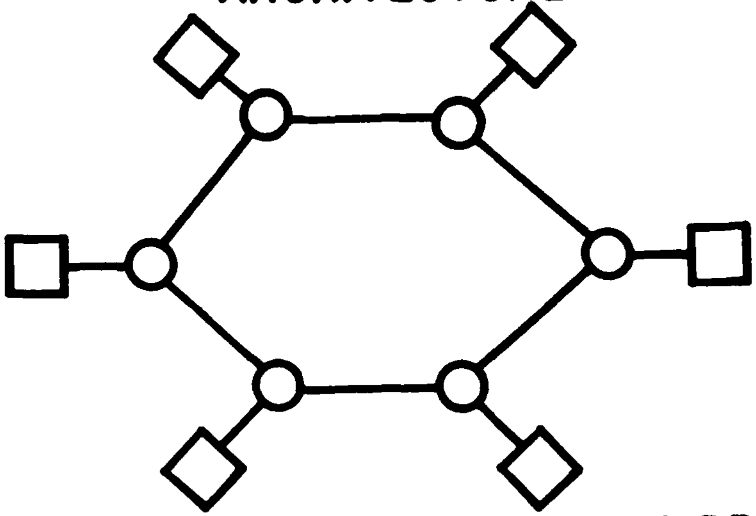
SINGLE / MULTIPLE CARRIER REQUIREMENTS

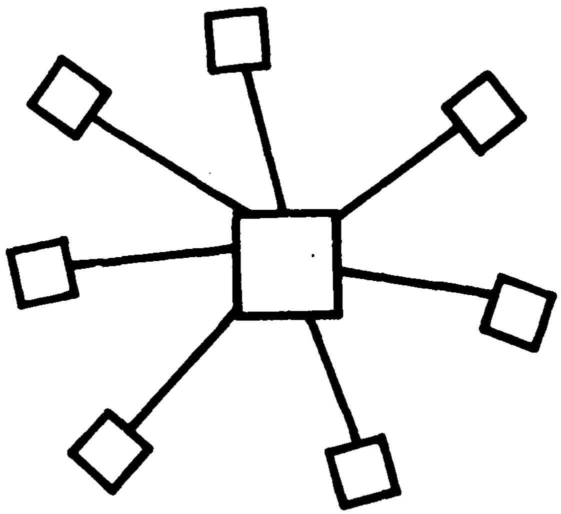
ABILITY TO HANDLE MANY NODES

MOBILITY

FIBER OPTICS

- WELL SUITED TO RING AND STAR TOPOLOGIES
- PRIMARILY USED FOR POINT TO POINT BASEBAND COMMUNICATION
- CAN HANDLE LONG DISTANCES
- CAN HANDLE VERY HIGH DATA RATES
- EMI, RFI SUSCEPTABILITY VERY LOW
- WHEN USED WITH RING TOPOLOGIES FAULT TOLERANT ARCHITECTURE NEEDED

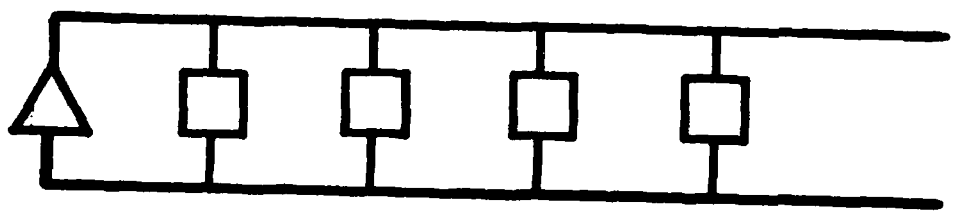




- EXAMPLES : FIBER CAMBRIDGE RING, GODDARD SPACE CENTER, FIBRENET, AFAL

COAX CABLE

- WELL SUITED TO BUS TOPOLOGIES
- CAN HANDLE A VERY LARGE NO OF USERS
- CAN SUPPORT MULTI-MEDIA COMMUNICATION
- VERY MATURE TECHNOLOGY
- LOW EMI, RFI SUSCEPTABILITY
- POWER CAN BE DISTRIBUTED ON SAME CABLE
- VERY LARGE THROUGHPUT WHEN AGGREGATED



- SUPPORTS BURSTY USERS WELL

EXAMPLES: HTACC, WIS ?, PENTAGON, ETHERNET, MITRENET

TWISTED PAIR

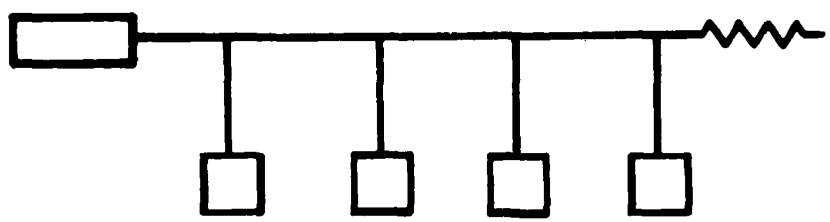
SUITABLE FOR BUS, STAR AND MESH TOPOLOGIES

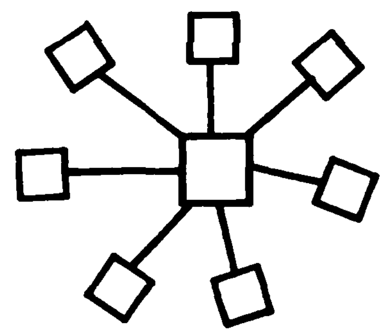
VERY INEXPENSIVE

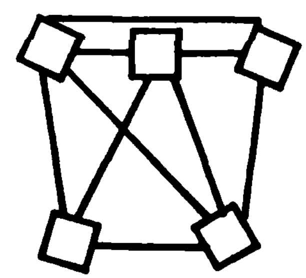
LIGHT WEIGHT

CAN HANDLE MODERATE DATA RATES FOR SHORT DISTANCES

BANDWIDTH LIMITED







EXAMPLES : MIL-S-1553, PABX, CAMBRIDGE RING

2 EXAMPLES OF AN ARCHITECTURE

FIBER OPTICS — GODDARD SPACE CENTER

COAXIAL CABLE — HTACC

A Multi-Loop Optical Fiber Network

Sylvania Systems Group
Communication Systems Division
GTE Products Corporation
77 A Street
Needham Heights, Mass. 02194 U.S.A.
Area Code 617 449-2000
TELEX: 92-2497

GTE **Systems**

7989-82

System Objective

To provide a high bandwidth system for Local Area Data Communications.

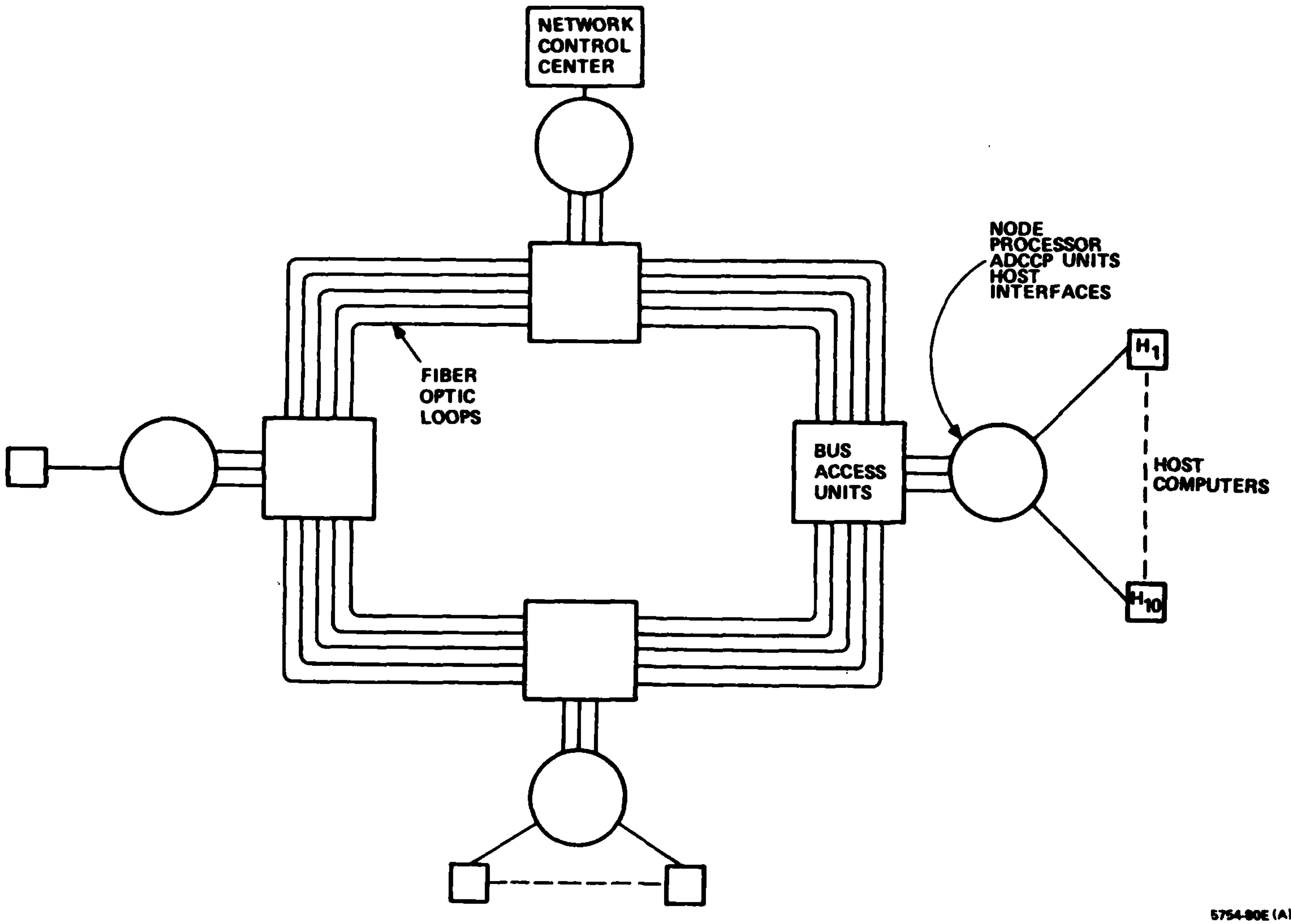
7970-82

NETWORK COMPONENTS

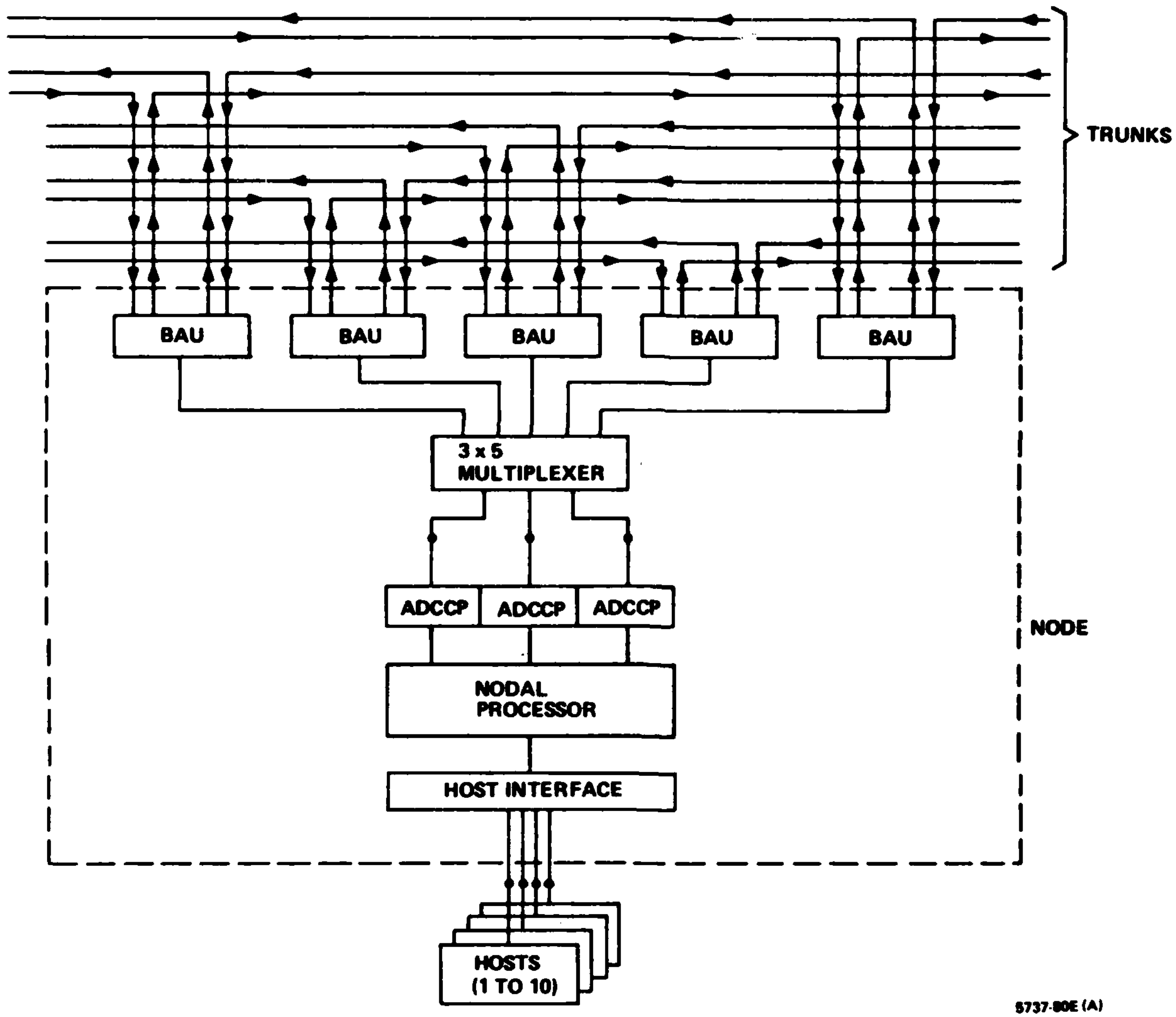
- OPTICAL FIBER CABLE
- BUS ACCESS UNIT
- MULTIPLEXER UNIT
- ADCCP UNIT
- NODAL PROCESSOR
- HOST INTERFACE
- NETWORK CONTROL CENTER

5795-80E

Multiloop Network Configuration



MULTILOOP NETWORK NODE



MULTILOOP ARCHITECTURE KEY CONCEPTS

- USE OF MULTIPLE LOOPS
  - PROVIDES HIGH AGGREGATE BANDWIDTH
  - ALLOWS ACHIEVABLE (STATE-OF-THE-ART) MESSAGE-PROCESSING SPEEDS
- EFFICIENT BANDWIDTH SHARING THROUGH CONTENTION PROTOCOLS
- ABLE TO HANDLE LONG FILE TRANSFERS
- FULL-DUPLEX LOOPS PROVIDE FAIL-SOFT MODE OF OPERATION
- FIBER OPTIC TRANSMISSION MEDIA
  - RELATIVELY EASY TO INSTALL IN EXISTING DUCTS
  - IMMUNE TO EMI AND CROSSTALK
  - ELECTRICAL ISOLATION BETWEEN NODES
  - RELATIVELY SECURE MEDIUM
  - EXISTING FIBER OPTIC SYSTEM ABLE TO MEET TRANSMISSION OBJECTIVES
  - ABLE TO CARRY HIGH-BANDWIDTH SIGNALS OVER LONG DISTANCES UNREPEATERED

7873-82

SYSTEM PERFORMANCE OBJECTIVES

- 20 Mb/s EFFECTIVE DATA TRANSFER RATE BETWEEN NODES
- 200 Mb/s AGGREGATE TRUNK BANDWIDTH
- FULL-DUPLEX, BIT-SYNCHRONOUS OPERATION AT INTERNODE DISTANCES UP TO 3000 FEET
- CONCURRENCY OF CONTROL AND DATA MESSAGES
- P (BE) < 10 (-9)
- ADCCP LINK-LAYER PROTOCOL ON NETWORK
- DYNAMIC ADDITION/DELETION OF HOSTS
- THREE NETWORK AND MULTIPLE HOST CONNECTIONS PER NODE
- INDIVIDUAL HOST CONNECTIONS FROM 9.6 kb/s THROUGH 20 Mb/s
- ADAPTIVE FLOW CONTROL OF HOST CHANNEL TRAFFIC

7972-82

FIBER OPTIC DATA BUS TECHNOLOGY AND APPLICATIONS

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ABSTRACT

This paper is intended to provide a general background on fiber optic data buses; i.e., what they are; why they are beneficial; what they look like; how they work; and where they are being used.

I. INTRODUCTION

A data bus is a communication system which interconnects a number of physically dispersed users (often called terminals) over a common communication channel (the bus). In most digital data buses, the bus is cooperatively shared by time division multiplexing (tdm) data transmissions. Data buses using twisted wire pair and coaxial cable have already been implemented in airplanes, ships, land vehicles, military tactical centers, space vehicles, and computing centers to reduce wiring, achieve system flexibility, and provide growth potential. These systems have proven data buses to be the strongest tool for integration of large complex systems because the data bus establishes a common basis for communication between all terminals. Terminals may be dropped, replaced, or new

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terminals may be added with minimum effort and without adversely affecting other operating terminals.

II. BENEFITS OF FIBER OPTICS

Fiber optics has many advantages over conventional wire which makes it a desirable transmission medium to consider for data buses. Some of these advantages are listed in Table 1. Fiber optic buses can do things that are impossible to do with wire while providing better performance, dramatic improvements in reliability, and reduced life cycle cost.

III. CONFIGURATIONS AND ARCHITECTUAL TRADEOFFS

A large variety of data bus configurations (topologies) and terminal architectures have been investigated for fiber optic data buses. Some very general representations of these configurations are illustrated in Figure 1. The most common fiber optic data bus configuration uses a single passive star coupler which distributes a signal from any one user to all users equally. The star configuration has the advantage of minimizing the number of couplers and connectors in the bus, thus minimizing optical loss. It also provides a relatively uniform range of signals at all receivers connected to the bus. The disadvantage of the star configuration is that it may require more cable than the tee configuration which is almost exclusively used in wire systems. The fiber optic tee configuration is typically limited to five to seven terminals

Table 1. Advantages of Fiber Optics.

Desirable Transmission Properties

- Greater bandwidth over longer distances; 200-1000 MHz·km typical for graded-index fibers
- Low signal attenuation; 3-5 dB/km at 0.85 μm wavelength; less than 1 dB/km at 1.3 μm wavelength
- Number of terminals is limited only by power considerations not signal distortion induced by taps on a wire bus

Enhanced Physical Characteristics

- Smaller
- Lighter weight
- More flexible and flexible over wide temperature range
- More elastic
- Not subject to flexural fatigue
- Corrosion resistant

Improved Reliability (Fewer Failure Mechanisms)

- Not electrically conductive, not a current path, electrically isolates terminals from each other, no shock hazard
- No possibility of short circuits or ground loops
- Intermittents are unlikely because intimate contact between fiber optic pins is not required to transmit the signal
- Safe in explosive environments
- Electrically isolates data bus terminals

Table 1. Advantages of Fiber Optics (continued).

Improved Channel Integrity

- Not affected by electromagnetic interference (emi) produced by power cables, switch closures, antennas, radiation from other signal wiring or electronic equipment, lightning, etc.
- Not affected by electromagnetic pulse (emp) associated with nuclear explosions. Electromagnetic pulse induced currents in wires connected to unprotected terminal equipment can result in equipment failure.
- Fiber optic cables do not radiate signals which might interfere with other systems.

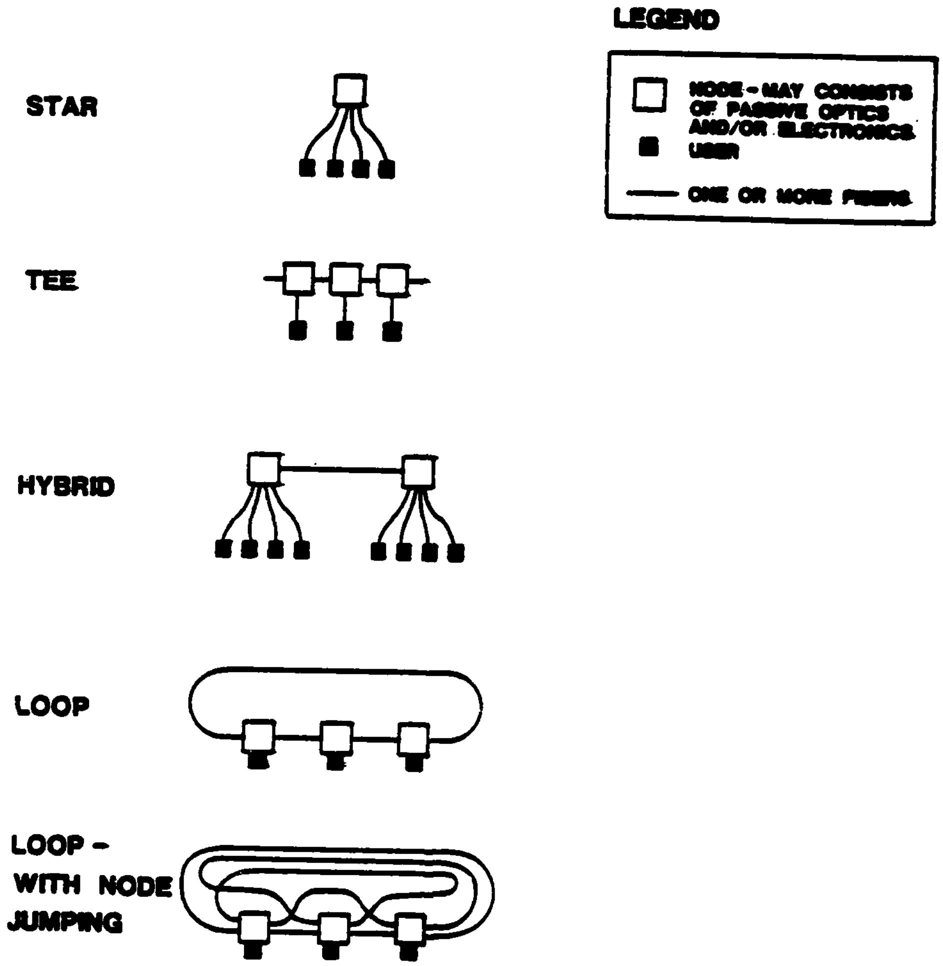

Figure 1. Data Bus Configurations.

unless repeaters are used because of the serial loss through connectors and tee couplers. Unfortunately, the equivalent of a high impedance tap analogous to wire bus couplers has not been developed for fiber optic systems.

Both passive and active (with repeaters) hybrid configurations have been developed which combine some of the advantages of the star and tee configurations. In the hybrid configuration couplers are located within clusters of users and only a few long cables are needed to interconnect between clusters.

Loop configurations have been devised which provide added redundancy over the basic tee configuration. If a break occurs; the bus reverts to a tee configuration. Since loop configurations are often based on use of repeaters at each node, passive node jumping is sometimes used to prevent failure of the loop bus due to repeater, connector, or fiber failure.

In all the configurations illustrated in Figure 1, nodes may consist of passive optical components and/or electronics; cables between nodes may consist of one or several fibers transmitting signals in one or both directions.

The bus configuration and terminal design selected for a specific application is typically based on a number of trade offs for a

given set of ground rules or basic system requirements. A list of some of the issues requiring a trade off analysis which are often encountered is given in Table 2.

IV. COMPONENTS

Optical Sources

Light emitting diodes (LED) composed of GaAlAs are presently the most suitable optical source for fiber optic data bus applications. Data rates of up to 150 Mb/s can be accommodated with LED sources. GaAlAs has good radiation resistance. Coupled powers of 100 μW (at 100 mA junction current) are typical for stripe geometry GaAlAs double heterojunction light emitting diodes. Recently, devices became available in full military grade versions which have hermetic packages and operate from -55°C to +125°C.

GaAlAs semiconductor laser diodes are useful at higher data rates, provide higher output powers than light emitting diodes and may also be suitable for some military applications in the near future. However, lasers generally require cooling and closed loop stabilization of the output power for operation over a wide temperature range and impose undesirable safety constraints.

Open loop stabilization and cooling above +70°C is desirable even for light emitting diodes. Variations in output power can occur due to the LED conversion efficiency's dependence on temperature

Table 2. Data Bus Issues.

Bus Design

- Topology
- Number of users
- Separation between users
- Number of fibers per cable
- Cable routing
- Cable type
- Connector type
- Growth potential

Terminal Design

- Encoding and decoding
- Synchronization
- Data detection (receiver design)
- Clock recovery
- Parallel to serial and serial to parallel conversion
- Data validation
- Built-in tests
- Data buffer
- Modularity
- Maintainability
- Safety

Table 2. Data Bus Issues (continued).

Transmission

- Source type
- Detector type
- Optical wavelength
- Modulation technique
- Data code
- Data format
- Link budget
- Rise time and dispersion

Performance

- Data rate
- Optical signal range (OSR)
- Receiver sensitivity and dynamic range
- Receiver intermessage dynamic range
- Bit error rate
- Data latency
- Bus loading efficiency
- Performance margins

Table 2. Data Bus Issues (continued).

Bus Control

- Bus access protocol
- Control protocol
- Failure modes

Environmental

- Temperature, etc.
- Hermetic sealing
- emi radiation and susceptibility (electronics)
- Nuclear radiation (electronics and optics)

Reliability

- Mean time between failures
- Mean time to repair
- Redundancy
- Availability

Cost

- Nonrecurring
- Recurring
- Cost of ownership

over the military temperature range. Above +70°C it is desirable to cool light emitting diodes to avoid degradation of device lifetime.

Optical Detectors

Silicon pin (p-type, intrinsic, n-type) photodiodes are presently the most common detectors for fiber optic data bus applications. The pin photodiodes are fast, efficient, low noise, and operate over a wide temperature range. Reversed biased pin diodes generate a photocurrent proportional to the optical signal power incident on the active area of the device.

Avalanche photodiode (APD) detectors provide greater sensitivity than pin photodiodes due to avalanche gain achieved in the device. However, a large reverse bias voltage (typically 300-400 V) is required. Avalanche photodiodes are used in a fixed gain configuration (rather than automatic gain control (agc)) to accommodate fast acquisition of data in data bus applications.

Fibers and Cable

Optical fibers which are recommended for data bus applications include the large core (100 μm) slightly graded-index fiber and the 50 μm core graded-index fiber (see Figure 2). Both fiber types have a borosilicate cladding and doped silica core to achieve the desired optical transmission characteristics. The

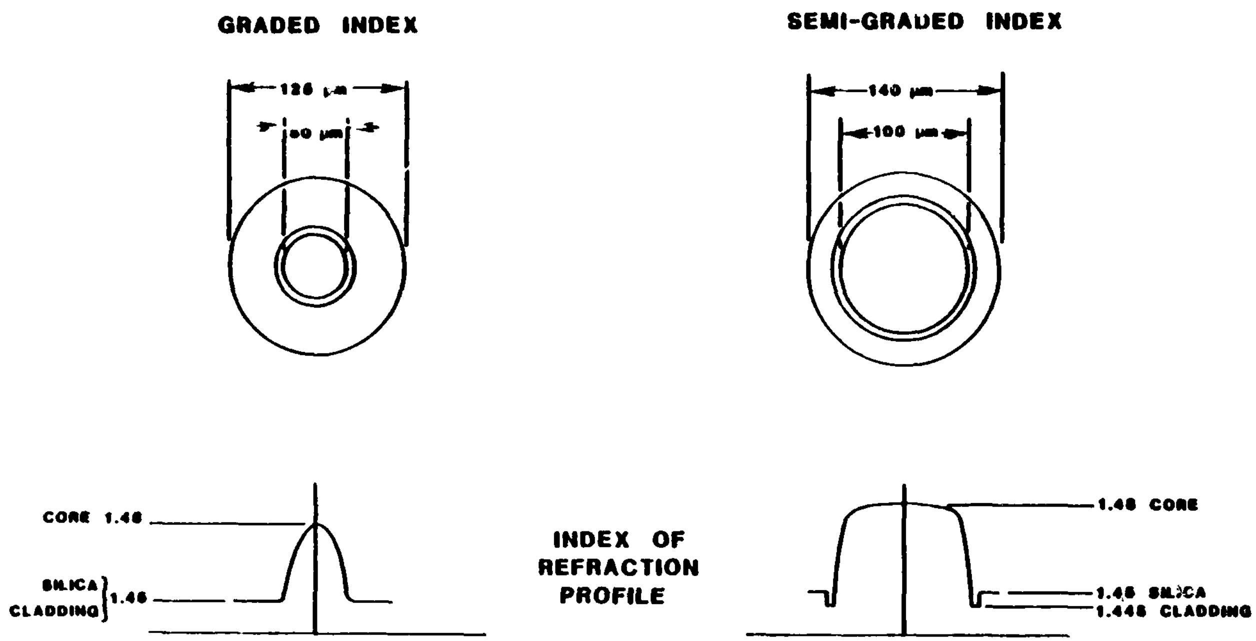

Figure 2. Optical Fibers.

large core slightly graded fiber is most suitable in short distance applications which have many connectors. The larger core results in lower loss connectors. However, fiber attenuation is 6-8 dB/km at 0.85 μm. The smaller core (50 μm) graded-index fiber has 3.5-5.0 dB/km attenuation at 0.85 μm and low dispersion which makes it more suitable for high data rate long distance applications. Both fibers are glass-glass constructions with a characteristically high mechanical strength. Fibers are typically tested to 100,000 psi during the manufacturing process. The glass cladding also provides a solid base for splice or connector installation.

Cables have been developed for surface tactical installations, underwater installations, aircraft installation, and a broad range of commercial direct burial, aerial mount, and duct installed applications (see Figure 3). The designs have proven adequate for wind buffeting and ice loading, installation pull, plowing under ground, and physical abuse under truck tires and armored vehicle tracks.

Couplers

A variety of directional, transmissive, reflective, and wavelength dependent optical couplers using either 50-μm or 100-μm core diameter all-glass fiber have been developed for use in fiber optic data bus systems. Samples are shown in Figure 4.

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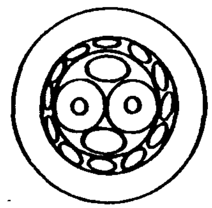
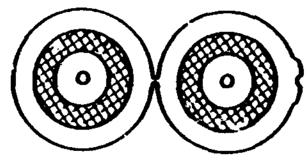
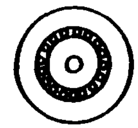
CROSS-SECTION			
JACKET MATERIAL:	POLYURETHANE	POLYURETHANE	TEFZIL
DIAMETER:	5.08 mm	3.05 mm (EA.)	2.5 mm
NUMBER OF FIBERS:	2, 4, 6	2	1
TENSILE STRENGTH:	67.0 Kgf	60.0 Kgf	67.0 Kgf
BEND RADIUS:	5.0 cm	3.5 cm	5.0 cm

Figure 3. Fiber Optic Cables.

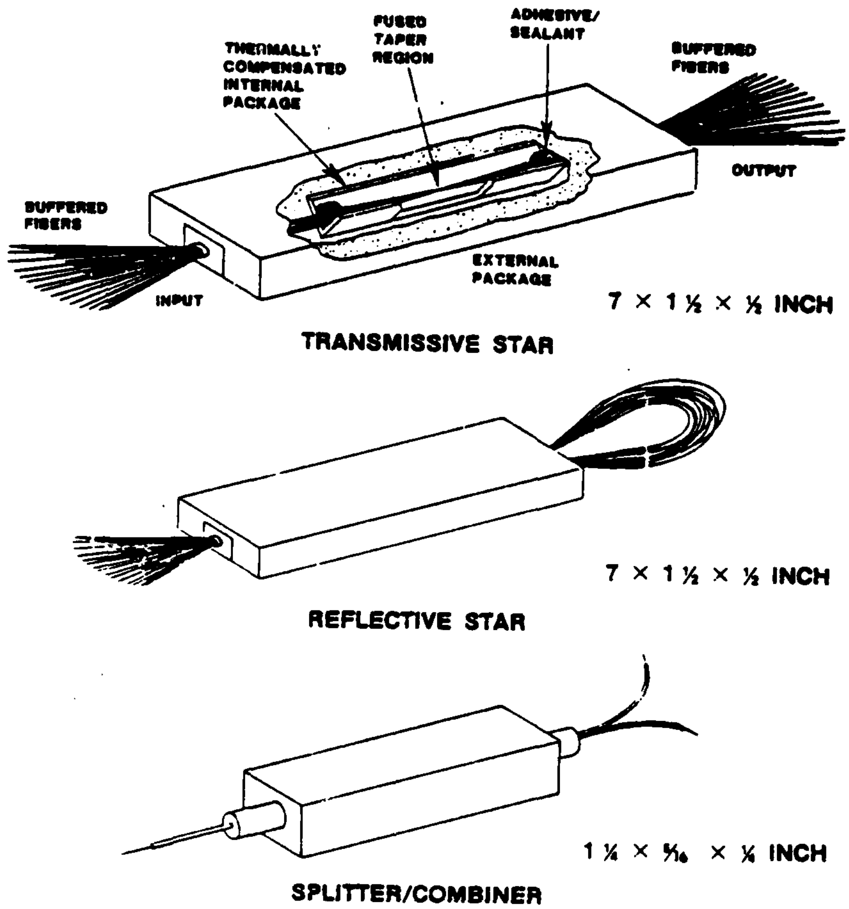
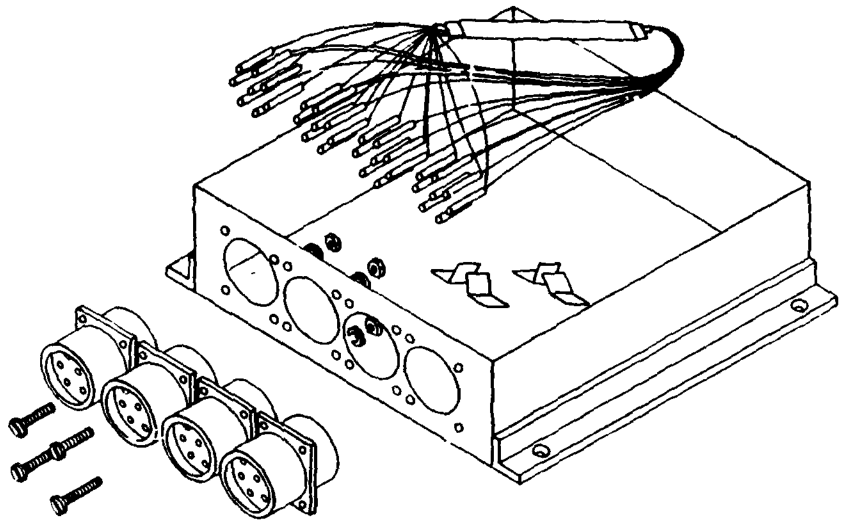


Figure 4. Optical Couplers.

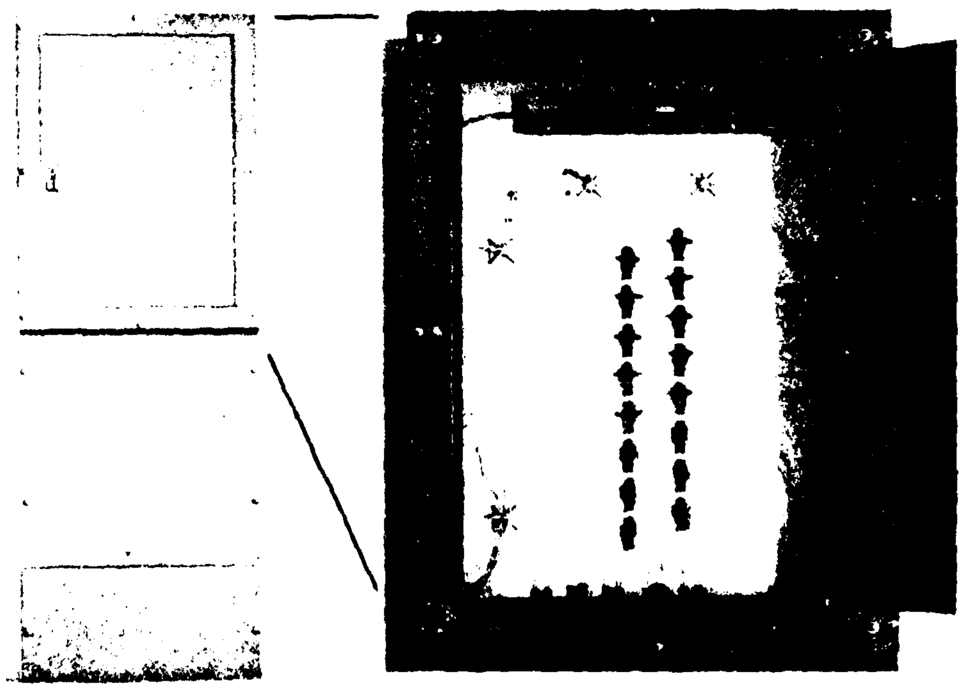
Optical performance and environmental stability of ITT EOPD couplers have been proven. The maximum excess loss of directional couplers with less than six ports is 2.0 dB. Larger directional couplers with up to 64 ports have less than 3 dB maximum excess loss. Reflection type couplers (used in systems to communicate bidirectionally over a single fiber) are specified to have less than 4.0 dB excess loss. Coupler uniformity, a measure of port-to-port output power variation, is specified to range from less than 10% to less than 40% depending on the number of coupler ports.

Environmental tests have been made on ITT couplers following a selected set of procedures from MIL-E-5400R and MIL-STD-810C. The tests have included high temperature, low temperature, temperature shock, humidity, vibration, and shock. The intent of the coupler test program is to fully comply with the requirements of MIL-E-5400R, Class 1A, for equipment to be used in piloted aircraft. Results of environmental testing to date have shown that the coupler designs can meet these requirements.

Optical couplers may be packaged with demountable connectors for easy replacement or spliced into the system as a permanent installation (see Figure 5). Modularity and mean time to repair (MTTR) are improved by providing connectorized couplers; however, often the connectors are more expensive than the coupler itself. This



a. Packaged With Connectors



b. Wallmount Installation

Figure 5. Coupler Packaging and Installation.

cost can be avoided by permanently splicing couplers into the bus with the added advantage of reduced loss.

Connectors

Connectors are often required at fire walls, pressure bulkheads, production breaks, couplers, and equipment interfaces. Both simplex and multiway fiber optic connectors have been developed by numerous connector manufacturers based on styles which have already become standards for wire systems (see Figure 6). Features desirable in an optical connector design include:

a. Ease of termination
b. Low insertion loss and repeatability
c. Long term reliability
d. Cable strain relief

Most fiber optic connectors to date use the butt joint alignment principle in which the fibers are aligned to each other by a precision metal, glass, ceramic, or plastic mechanical assembly. In these systems, the main cause of optical loss is radial (transverse) fiber offset which must be controlled to about 5 μm (0.0002 in) or less to achieve a low-loss connector.

The optical losses associated with end separation, angle mismatch, and Fresnel reflection are usually much lower than for radial offset. Commercially available multifiber connectors using the butt

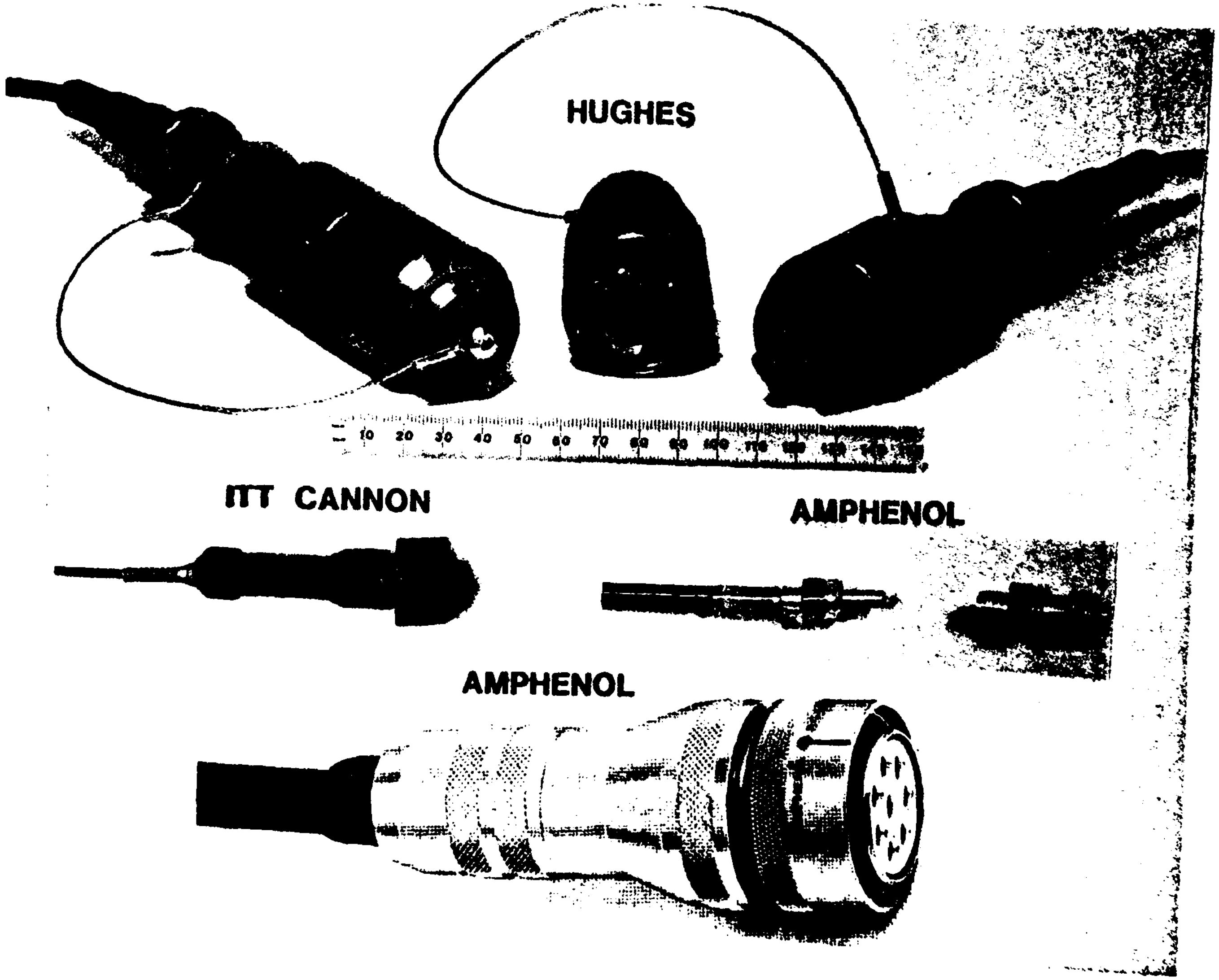


Figure 6. Fiber Optic Connectors.

joint technique have typical optical insertion losses of 0.5 dB to 3.0 dB. As connectors improve, connectors should become available with losses consistantly below 1.0 dB.

V. DATA RECOVERY

Data transmissions in fiber optic data buses are typically bursty, asynchronous, varying in amplitude, closely spaced, and high speed. Recovery of data requires that the receiver, data detection scheme and clock recovery scheme take into account the unique characteristics of the received data bus transmissions.

Data Bus Receiver

A typical receiver for point-to-point applications uses a pin photodiode or an APD to convert a small intensity modulated optical signal into a signal photocurrent. A carefully designed low-noise amplifier is used as the first stage in a number of successive gain stages to amplify the signal to levels suitable for threshold detection.

In point-to-point links, agc is often used to adjust the signal to an optimum level for detection with a voltage comparator. The agc process used in point-to-point links generally has a long convergence time and is not suitable for data buses where data transmissions are short and change in amplitude between adjacent transmissions. Therefore, an optical data bus receiver is unique

in that it must accommodate a large range of input signal levels and have a very short acquisition time.

Unlike bipolar electrical signals, intensity modulated optical signals are unipolar and a change in the received signal amplitude results in a change in the average value (see Figure 7). The term optical signal range (OSR) has been used to describe the magnitude of this change and is defined as the ratio of the average or peak powers, expressed in decibels.

The term dynamic range has been traditionally used to refer to the total range over which a receiver can operate. The range is generally limited by saturation at one extreme and by noise at the other extreme. However, because of the short acquisition time requirement, the term dynamic range is not entirely adequate for characterizing optical data bus receivers. Therefore, the new term, intermessage dynamic range (IDR), has been defined for characterizing optical data bus receiver performance. IDR is defined as the maximum OSR that a receiver can accommodate when separated by a minimum intermessage gap, t_g. The challenge is to design an optical receiver for use in data bus applications which can tolerate a very large OSR for very small t_g.

Receiver designs may be divided into three types: switched, linear, and nonlinear (see Figure 8). Switched designs include

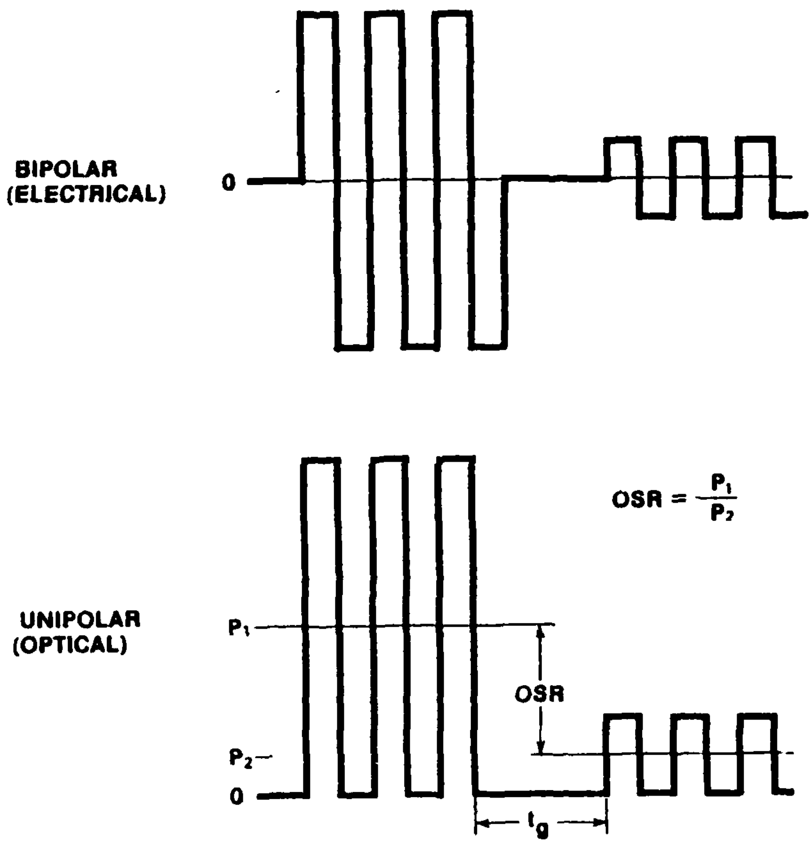


Figure 7. Intermessage Dynamic Range.

adaptive threshold and fast response agc. Linear designs can be used if additional interface electronics is provided between the transmitter/receiver and the host. Such schemes include narrow pulse Manchester, edge detection, three-state Manchester, and frequency shift keying (fsk). ITT's receiver design employs the nonlinear approach.

The ITT symmetrical clamp receiver design was recently optimized for use on a 1 Mb/s transceiver card for MIL-STD-1553 (an aircraft multiplex bus standard) (see Figure 9). The design is architecturally more attractive than switched designs because it does not require a control signal from the data decoder to initialize the receiver prior to a message and is more reliable and economical than linear designs because additional interface electronics is not required. Waveforms for the symmetrical clamp receiver are shown in Figure 10. The waveforms represent a 23.0 dB (200:1) OSR for a 2 bit separation between transmission (as required by MIL-STD-1553). The sensitivity achieved with this design is -52.0 dBm (6 nW). A 16.0 Mb/s version of the receiver has also been developed by ITT for Litton Data Systems for use in the TAOC-85 program, U.S. Marine Corps.

Clock Recovery

Clock recovery is a key consideration in any asynchronous communication system. Poor timing can result in burst errors which can

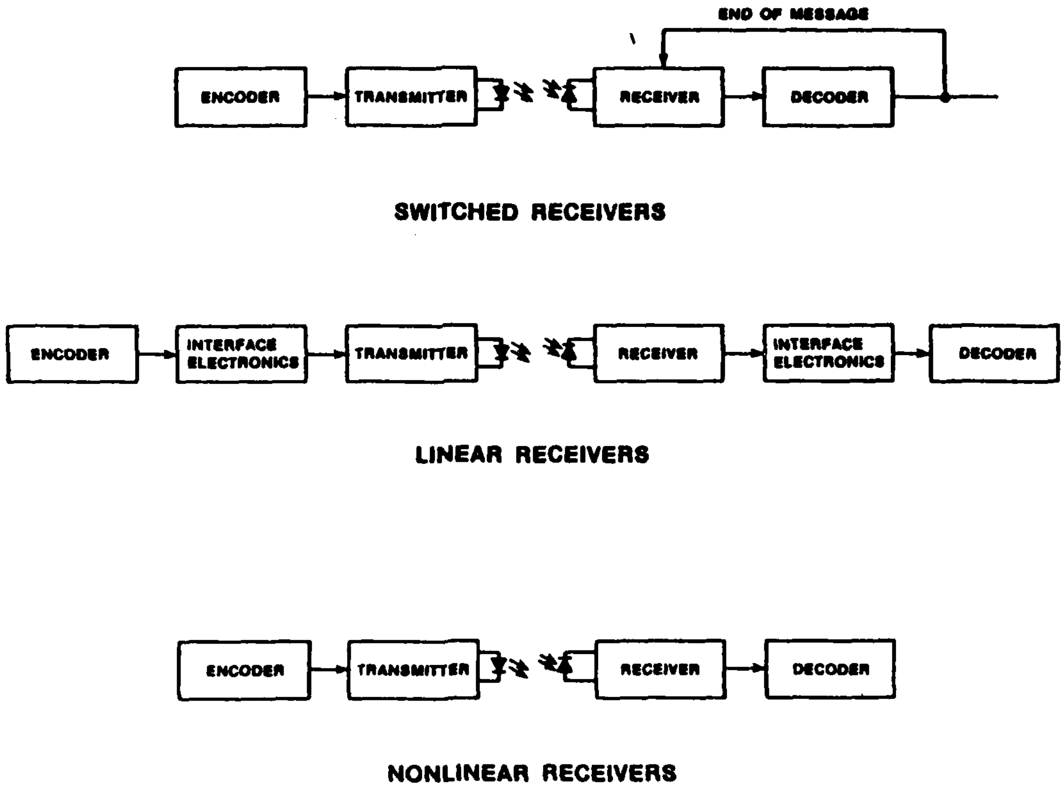


Figure 8. Architectural Implications of Receiver Types.

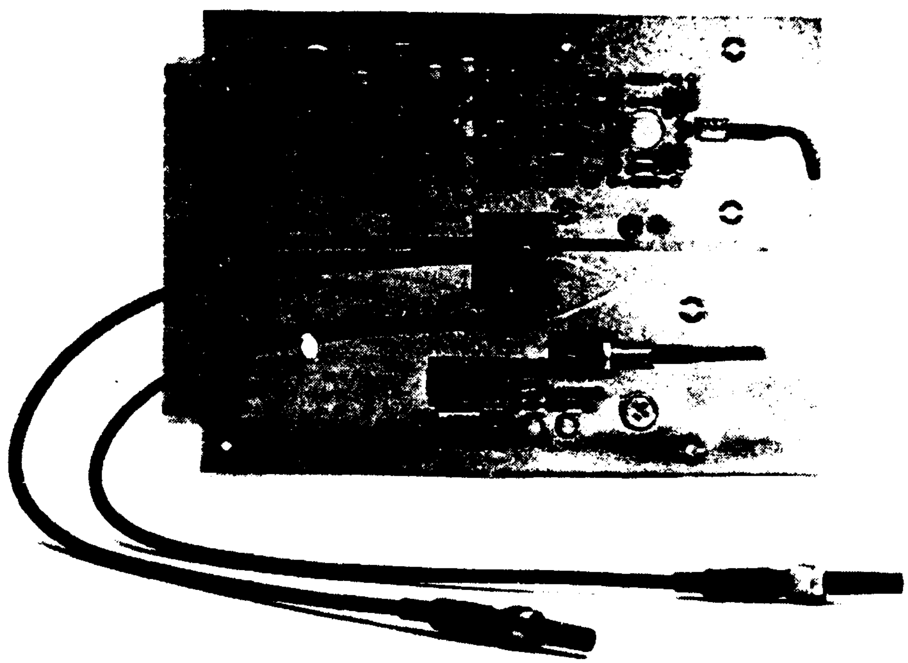


Figure 9. 1 Mb/s Data Bus Transmitter/Receiver Card.

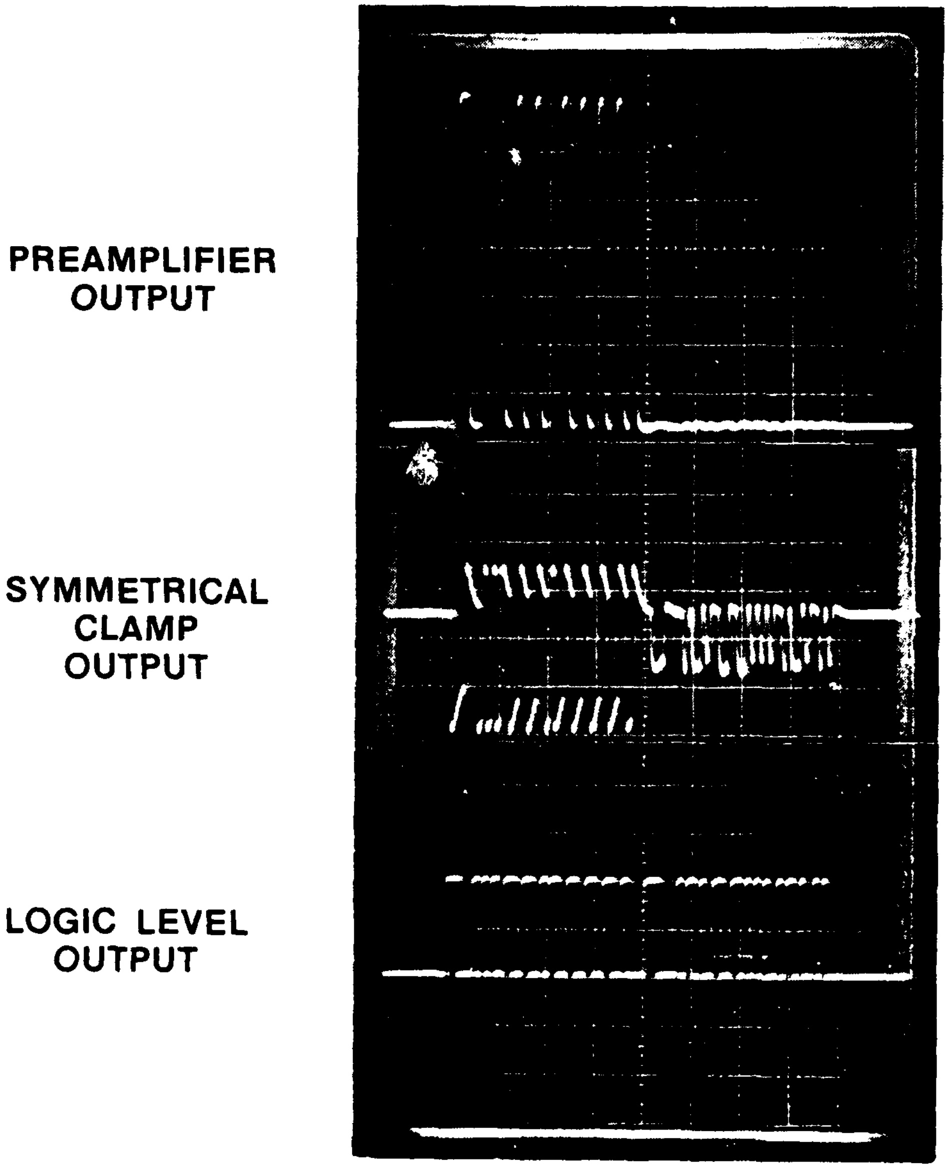


Figure 10. Data Bus Receiver Waveforms.

increase error rates by orders of magnitude over error rates resulting from purely additive noise. Clock recovery for data buses is generally more difficult than for continuous systems because data is bursty and asynchronous. In addition, clock must be acquired very quickly to maintain high bus loading efficiencies, especially when bursts of data are short.

Encoding (such as Manchester biphase) is often used to provide a strong frequency component from which clock can be easily derived. Manchester code guarantees a transition in the center of each bit. Both digital and analogue techniques are used to derive clock from the received data. At low data rates digital techniques are more common. Analogue techniques using tuned circuits become easier at higher data rates.

VI. DATA BUS PERFORMANCE

A summary of the performance of a 100 Mb/s fiber optic data bus system recently developed by ITT for NASA-Marshall Space Flight Center (see Figure 11) is graphically illustrated in Figure 12. The OSR of 5.6 dB (-24.6 dBm to -19.0 dBm) is derived from measured star coupler loss (including connectors) and a -3.7 ±0.7 dBm coupler power. The 18.8 dB receiver dynamic range can be adjusted upward or downward by several decibels by adjusting receiver gain. All data bus terminals have been set for a sensitivity level (bit error rate (BER) $\leq 10^{-10}$) of -31.0 dBm and

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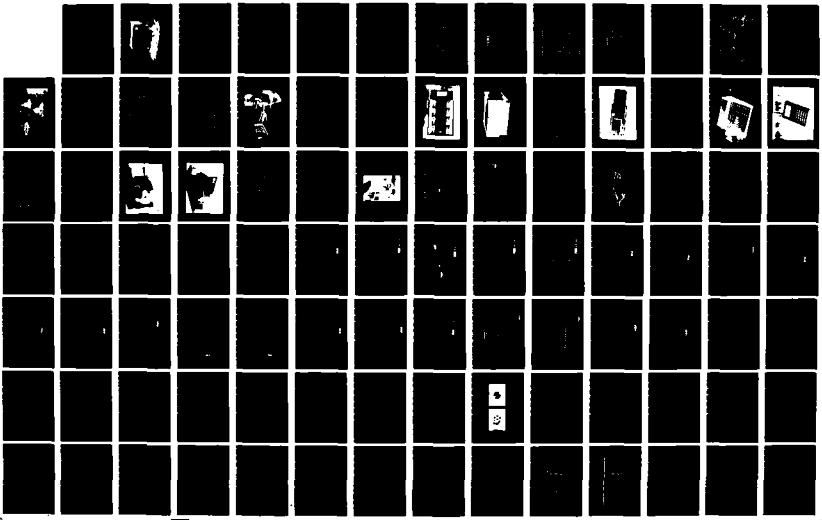

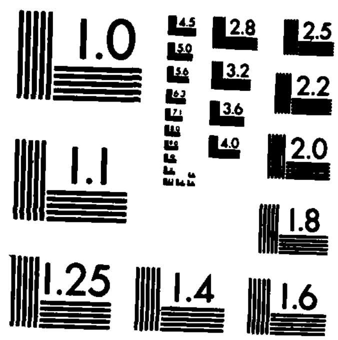

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

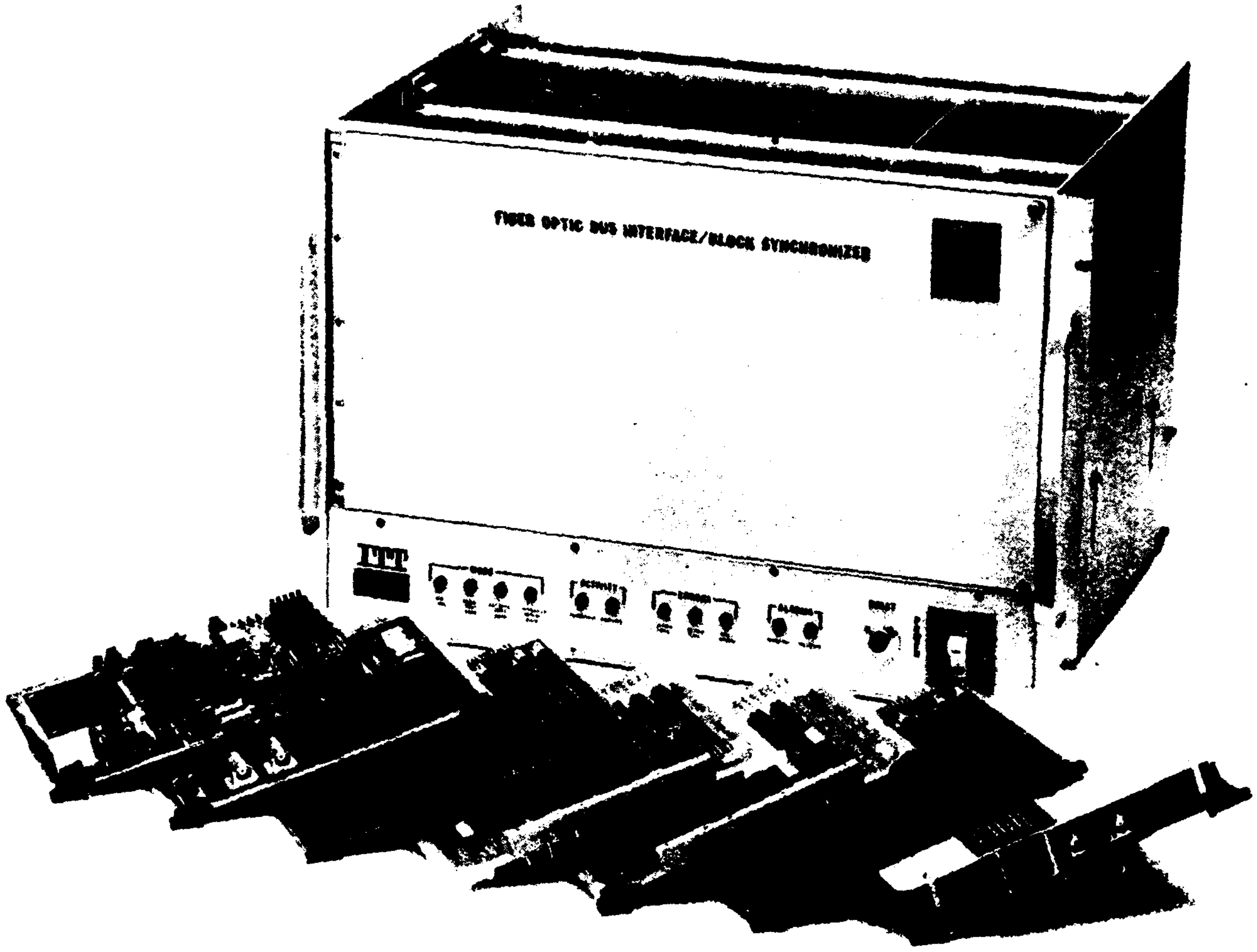

Figure 11. 100 Mb/s Data Bus Terminal.

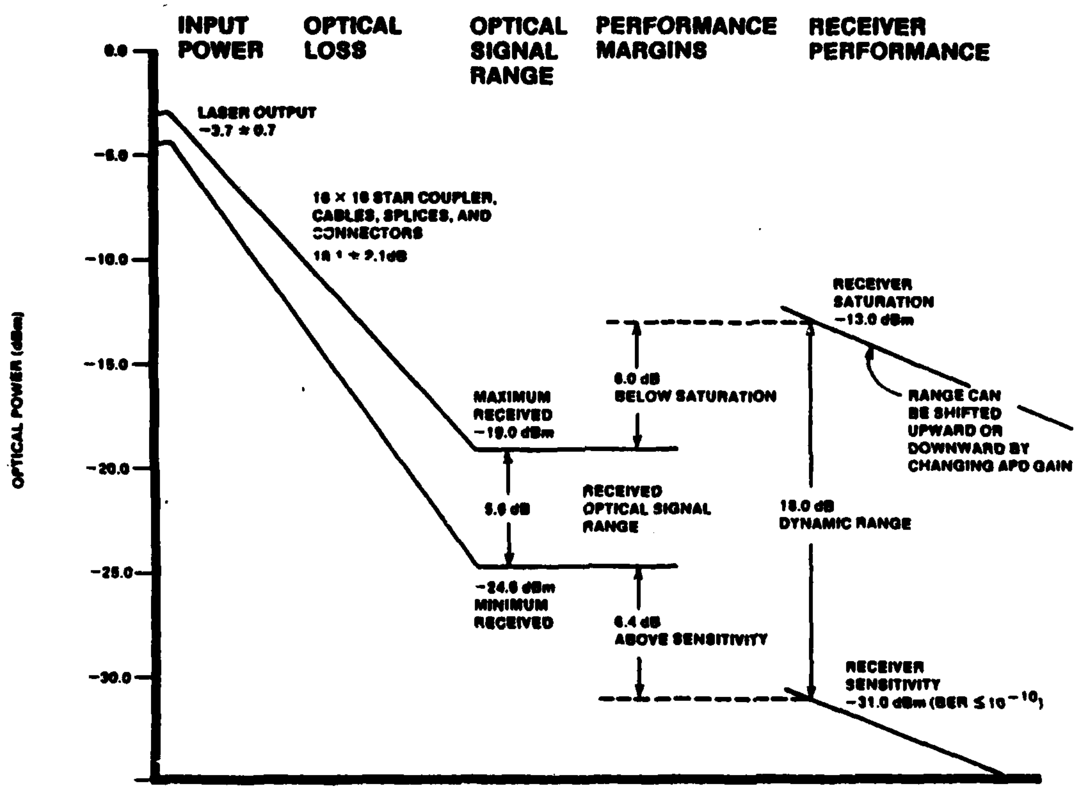

Figure 12. 100 Mb/s Data Bus Performance Summary.

a sensitivity level (bit error rate (BER) $<10^{-10}$) of -31.0 dBm and saturation level of -13.0 dBm. Therefore, the margin above the sensitivity level is 6.4 dB optical and below saturation is 6.0 dB optical.

VII. BUS ACCESS AND CONTROL

The resources of a data bus must be shared in an orderly fashion by all terminals to achieve high efficiency. For this reason a protocol for bus access (decision to transmit) and control of messages (content, origin, and destination) must be adopted.

The bus access protocol is the set of rules adopted by all data bus terminals to govern which terminal gains access to the bus at a given instant. The overall objective is to utilize the bus communications resource in the most efficient manner. Parameters of interest are bus loading efficiency, average wait time, and maximum wait time. No single bus access protocol has yet emerged which meets the needs of all applications equally well. There are presently a number of industry efforts to standardize on a bus access protocol. However until standards emerge, bus access protocol will continue as an issue of consideration for system designers. Popular bus access protocols include:

a. Command/response (MIL-STD-1553)

b. Time slot allocation

c. Dynamic time slot allocation

d. Carrier sensed multiple access with collision detection (CSMA/CD)

e. Token passing

Even fewer standards exist for message control. Issues relating to control protocol include:

a. Buffer sizes

b. Message size and format

c. Issuing commands

d. Status reporting

e. Message routing

VIII. DATA BUS APPLICATIONS

Data buses have gained acceptance in both commercial and military applications; in ground based, airborne, sea going, and spacecraft installations; and throughout almost every discipline; e.g., data base, strategic, tactical, medical, financial, control, etc. Data buses have been used to transmit digital data, analog data, digitized analog data, voice, video, and radar signals. Only imagination appears to limit the range of applications for data buses. Data bus technology began in the 1960's and rose to full prominance in the 1970's with wire technology as the principle transmission medium. The 1980's will see broad applications of data buses using both wire and fiber optics. Perhaps the 1990's will predominantly belong to fiber optics.

IX. CONCLUSIONS

Fiber optic data bus technology offers many tangible benefits over wire technology. These benefits have been noted earlier in this paper. Fiber optics technology has matured considerably in the last several years and the components and techniques are available today to take advantage of the benefits offered by fiber optic systems.

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TELECONFERENCING

FIBER-OPTIC

COMMUNICATION SYSTEM

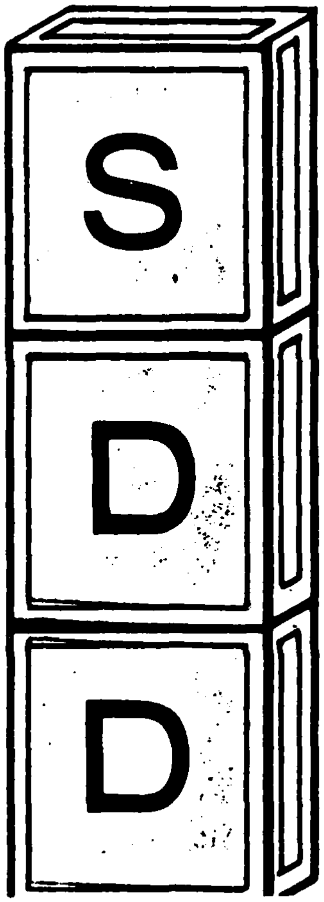
THEME

Ground Communications

Must Survive

Future Electronic/Physical Threats

PERCEIVED NEEDS



SURVIVABLE

DECENTRALIZED

DISPERSION

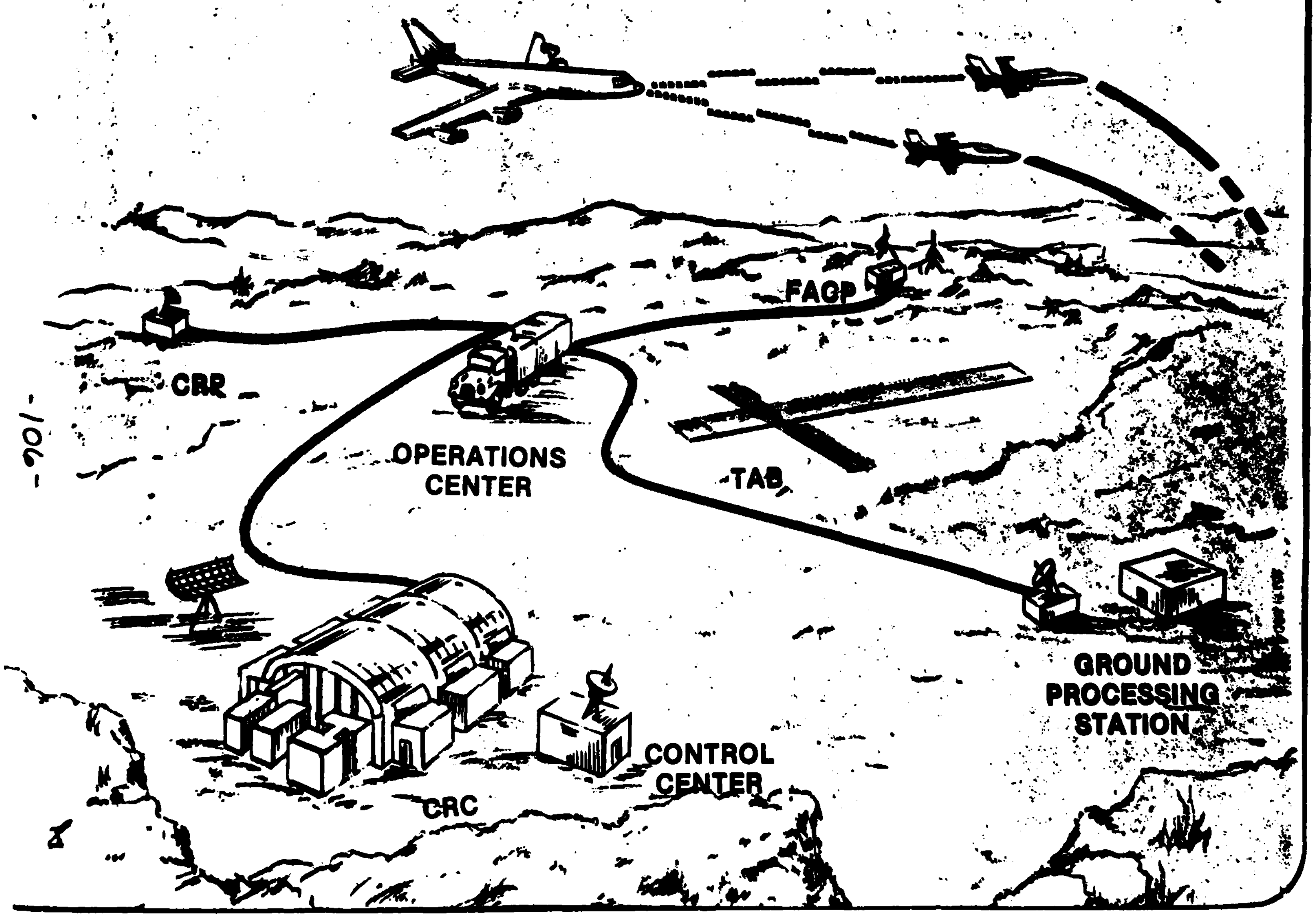
ISSUES

- Dispersion Enhances Survivability
- Dispersion Creates C^2 Problems
- Rapid Technology Changes Underway

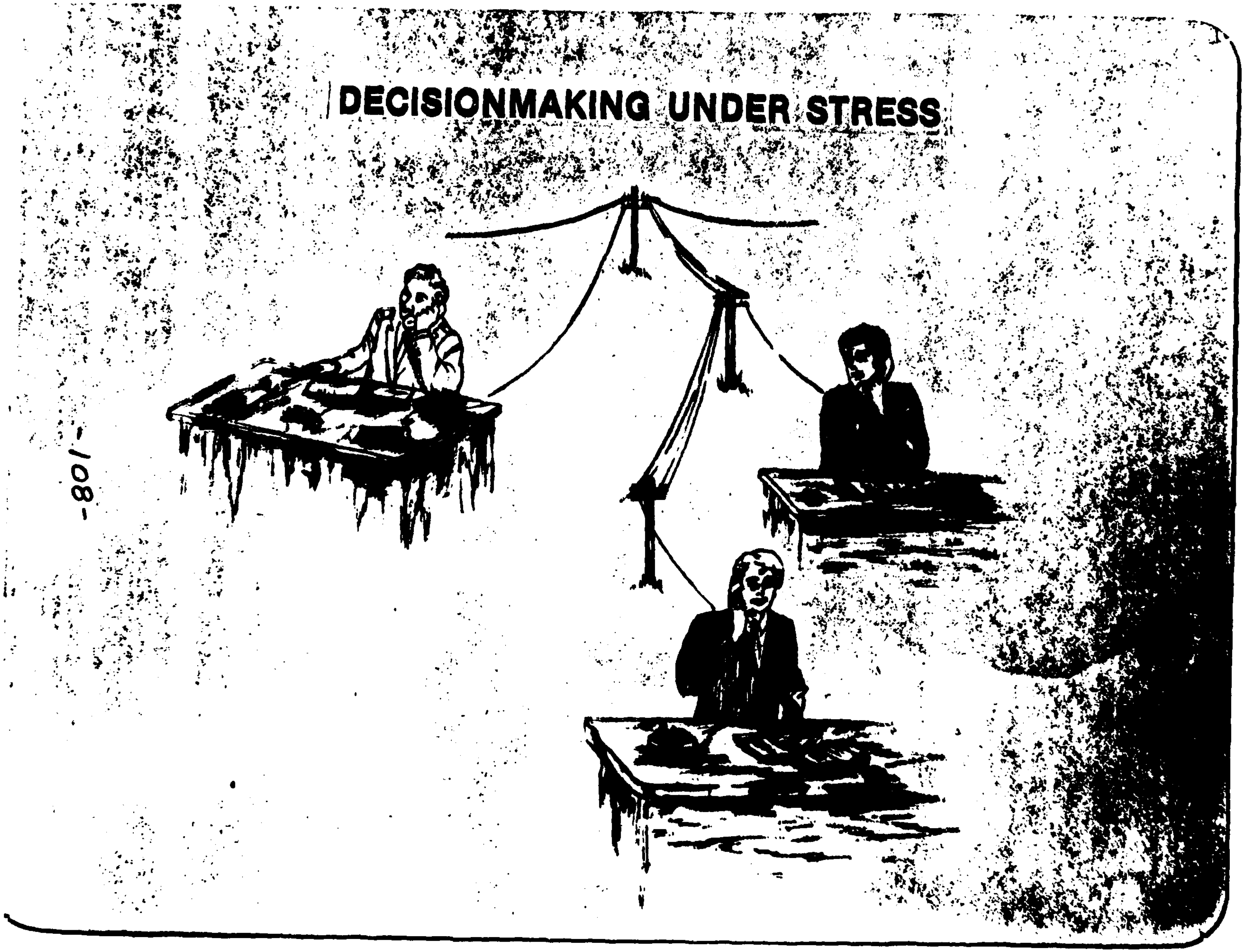
CELLULAR COMMAND POST CONCEPT

- Small Functional Cells
- Common Structure Duplicated
- Highly Mobile
- 5-10 km Apart

AF DEPLOYMENT



DECISION—MAKING UNDER STRESS


DECISIONMAKING UNDER STRESS

VIDEO TELECONFERENCING

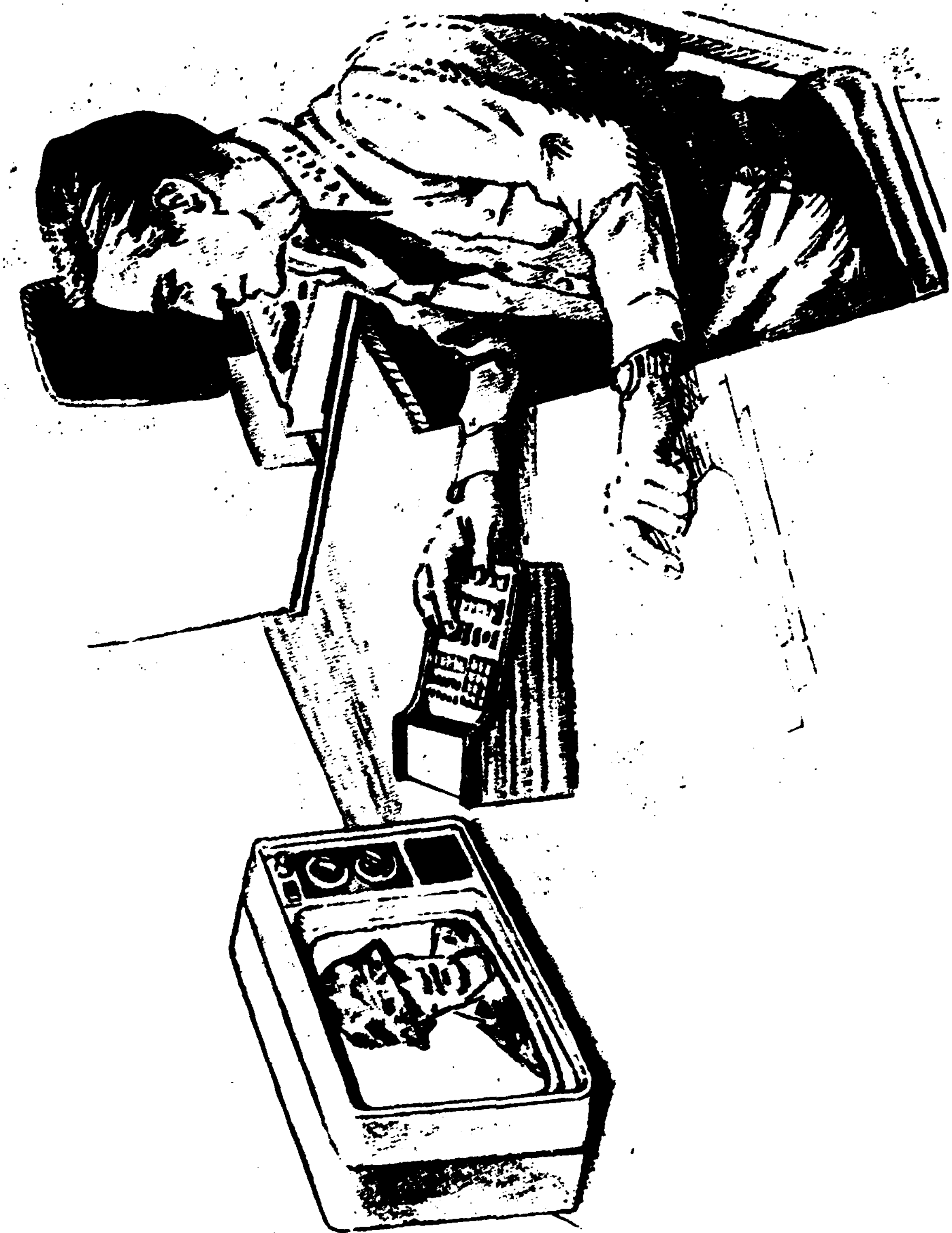
AS A SOLUTION

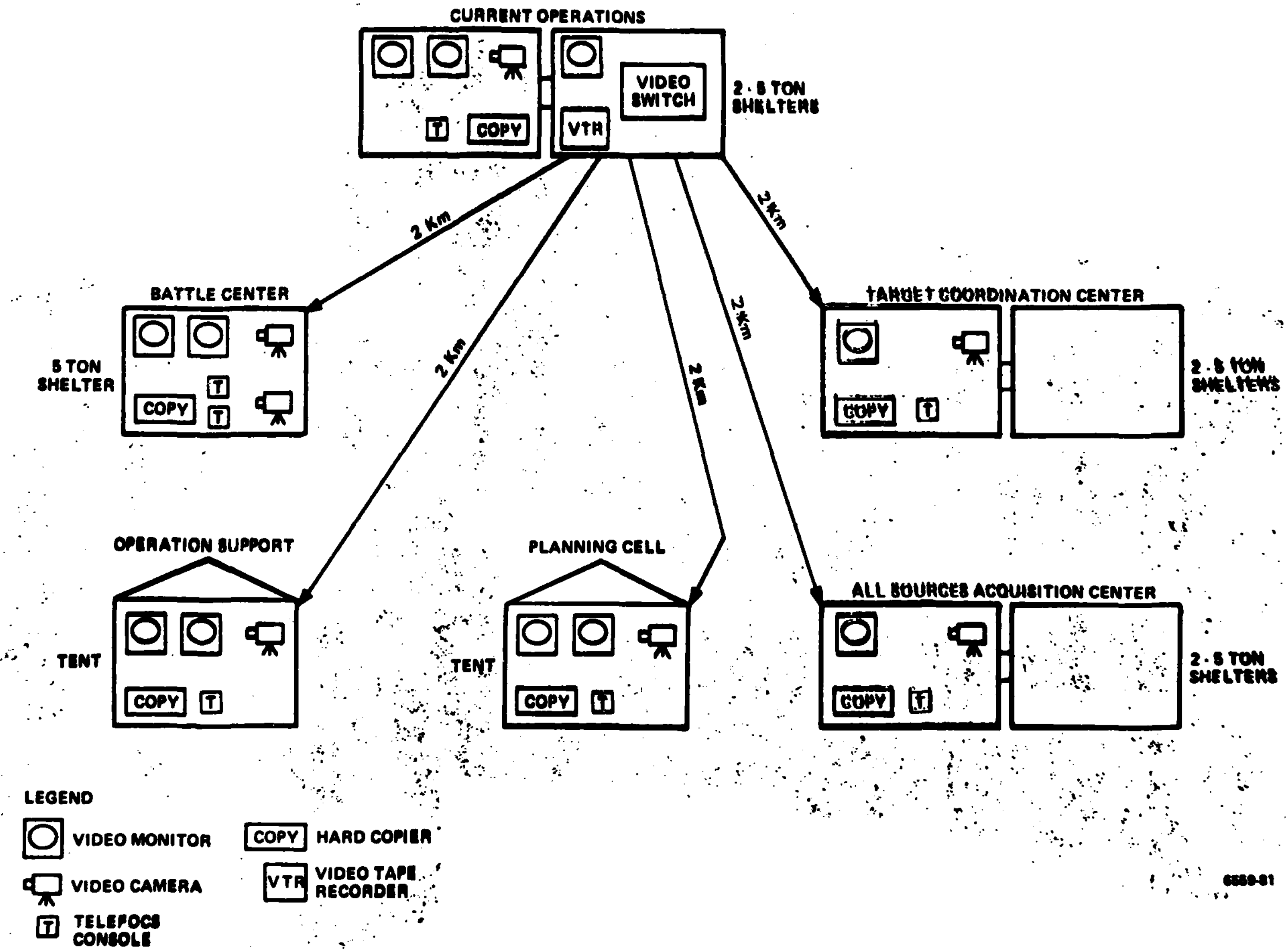
VIDEO CONFERENCING FUNCTIONS

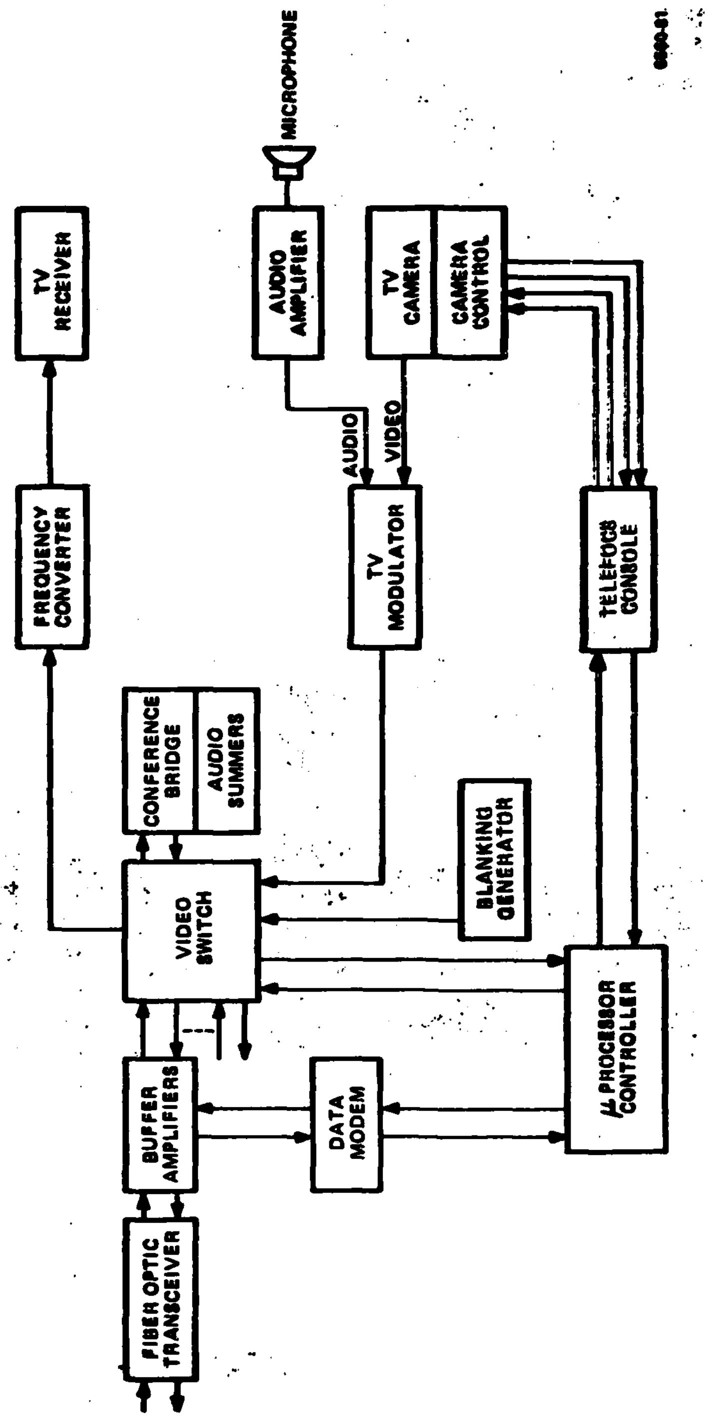
- Multi-Location
- Full-Motion
- Color
- Location
  - Conference
  - Office
- Picture Presentation
  - Full-Screen
  - Split-Screen
- Picture Content
  - Person
  - Graphics/Document
- Camera Control

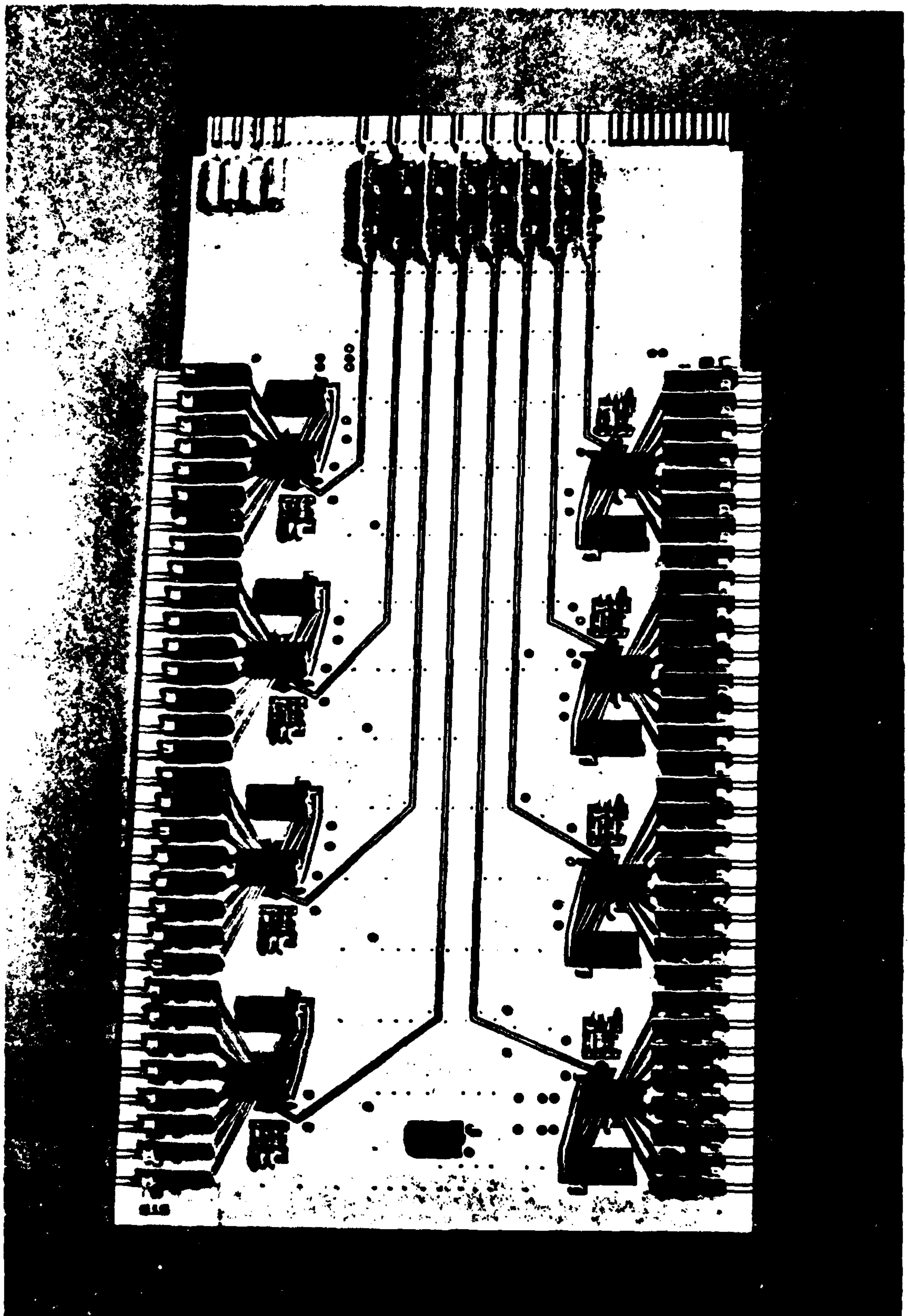
VIDEO CONFERENCING APPROACH

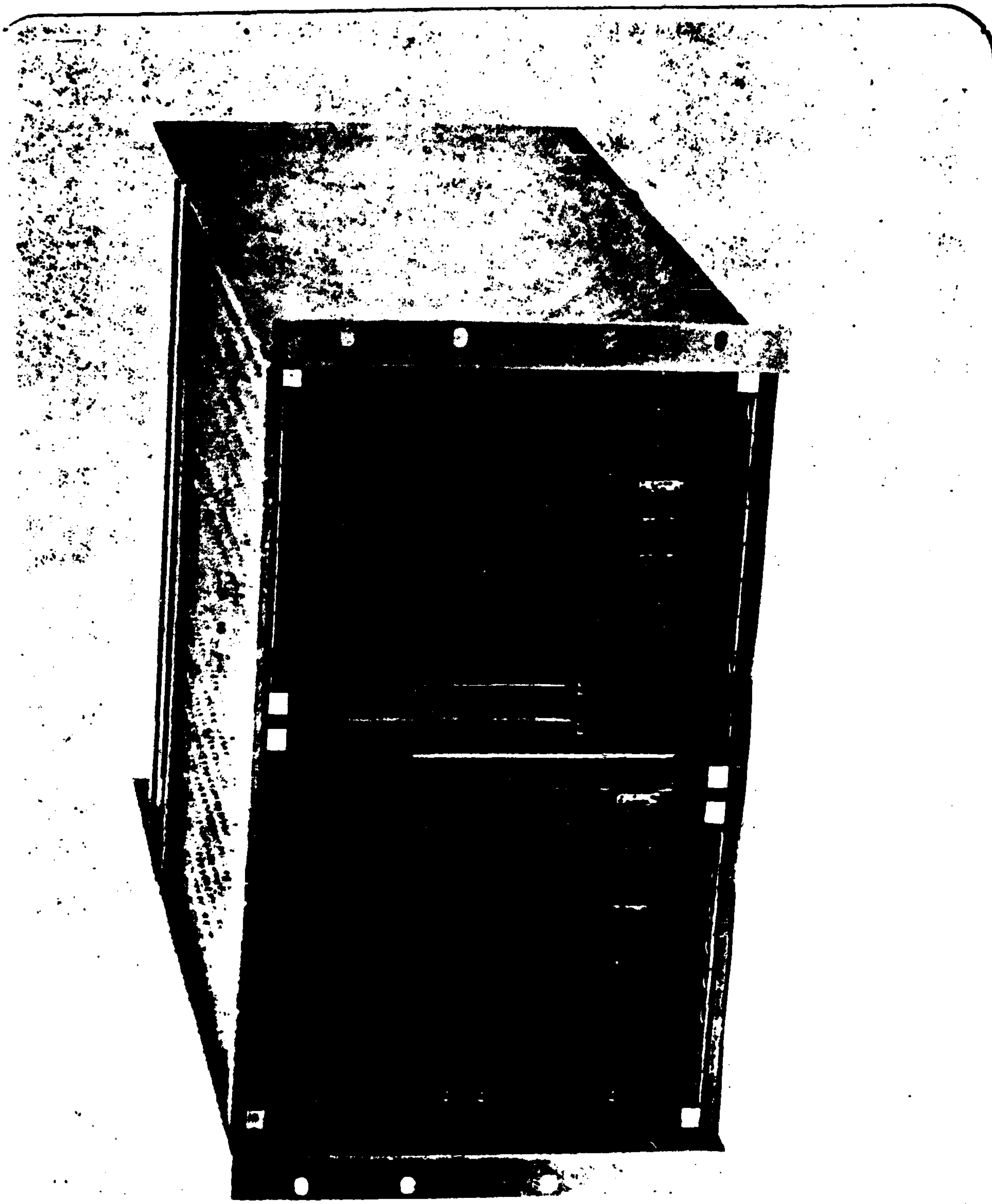
- Analog Optical Fiber Transmission
- Standard TV Set
- 1 Standard Camera per Site
- Star Network
- Multiservice Flexibility



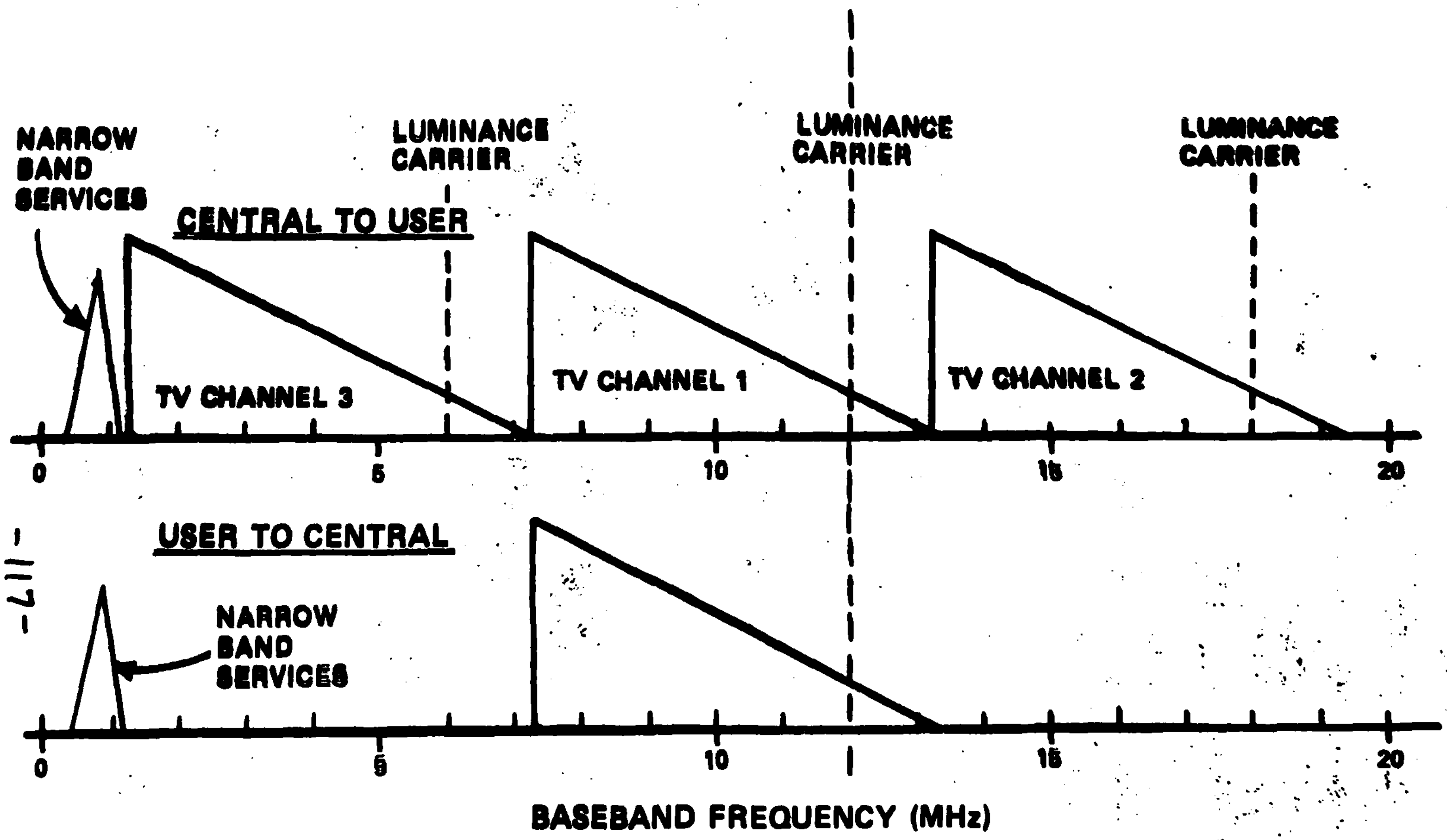

CURRENT OPERATIONS
COPY
VTR
VIDEO SWITCH
2 - 5 TON SHELTERS
2 Km
2 Km
2 Km
2 Km
2 Km
BATTLE CENTER
5 TON SHELTER
COPY
TARGET COORDINATION CENTER
COPY
2 - 5 TON SHELTERS
OPERATION SUPPORT
TENT
COPY
PLANNING CELL
TENT
COPY
ALL SOURCES ACQUISITION CENTER
COPY
2 - 5 TON SHELTERS
LEGEND
VIDEO MONITOR
VIDEO CAMERA
TELEFOCS CONSOLE
COPY HARD COPIER
VTR VIDEO TAPE RECORDER

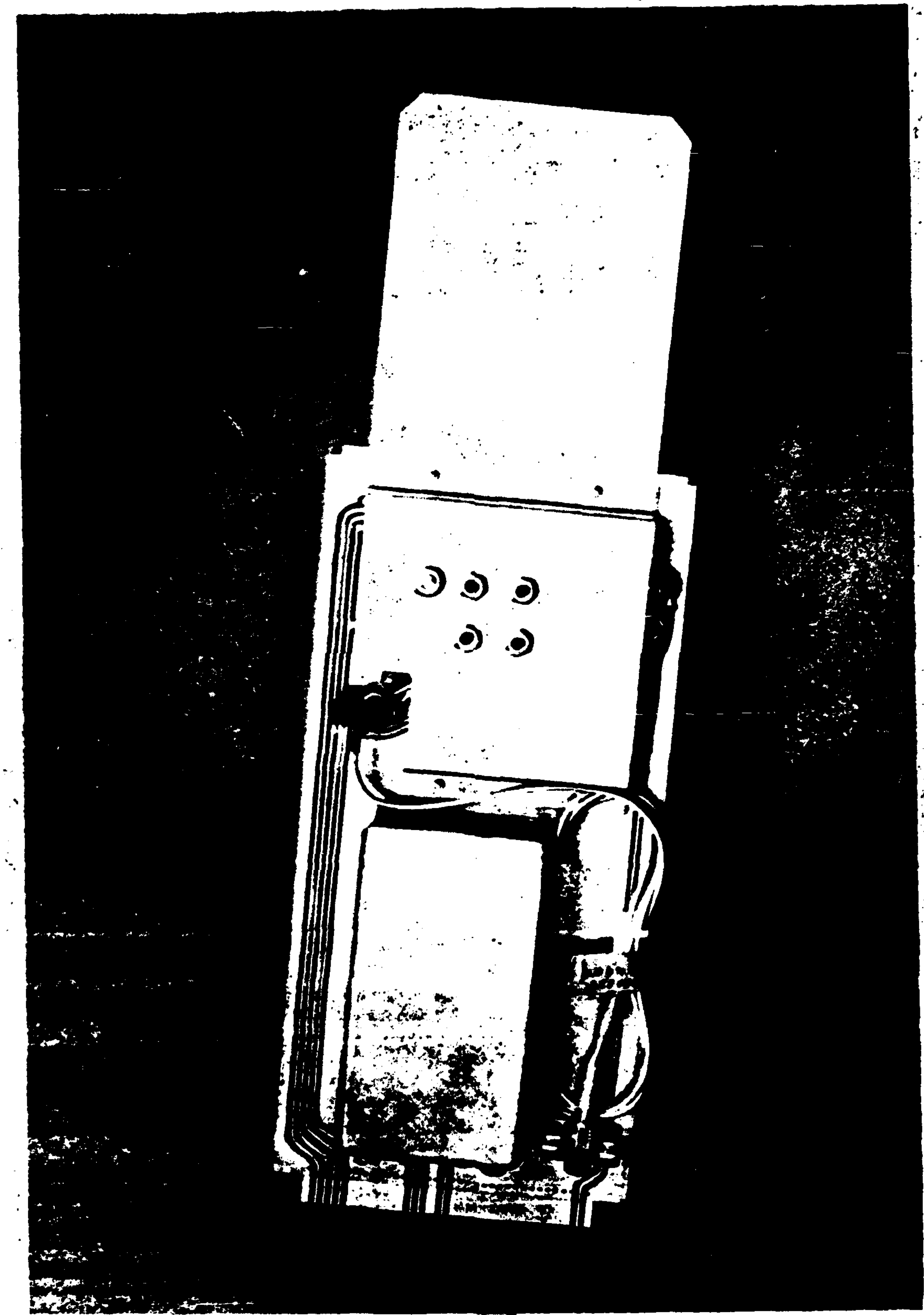

TV RECEIVER
FREQUENCY CONVERTER
AUDIO AMPLIFIER
MICROPHONE
TV CAMERA
CAMERA CONTROL
AUDIO
VIDEO
TV MODULATOR
TELEFOCS CONSOLE
CONFERENCE BRIDGE
AUDIO SUMMERS
BLANKING GENERATOR
VIDEO SWITCH
μ PROCESSOR CONTROLLER
BUFFER AMPLIFIERS
DATA MODEM
FIBER OPTIC TRANSCEIVER

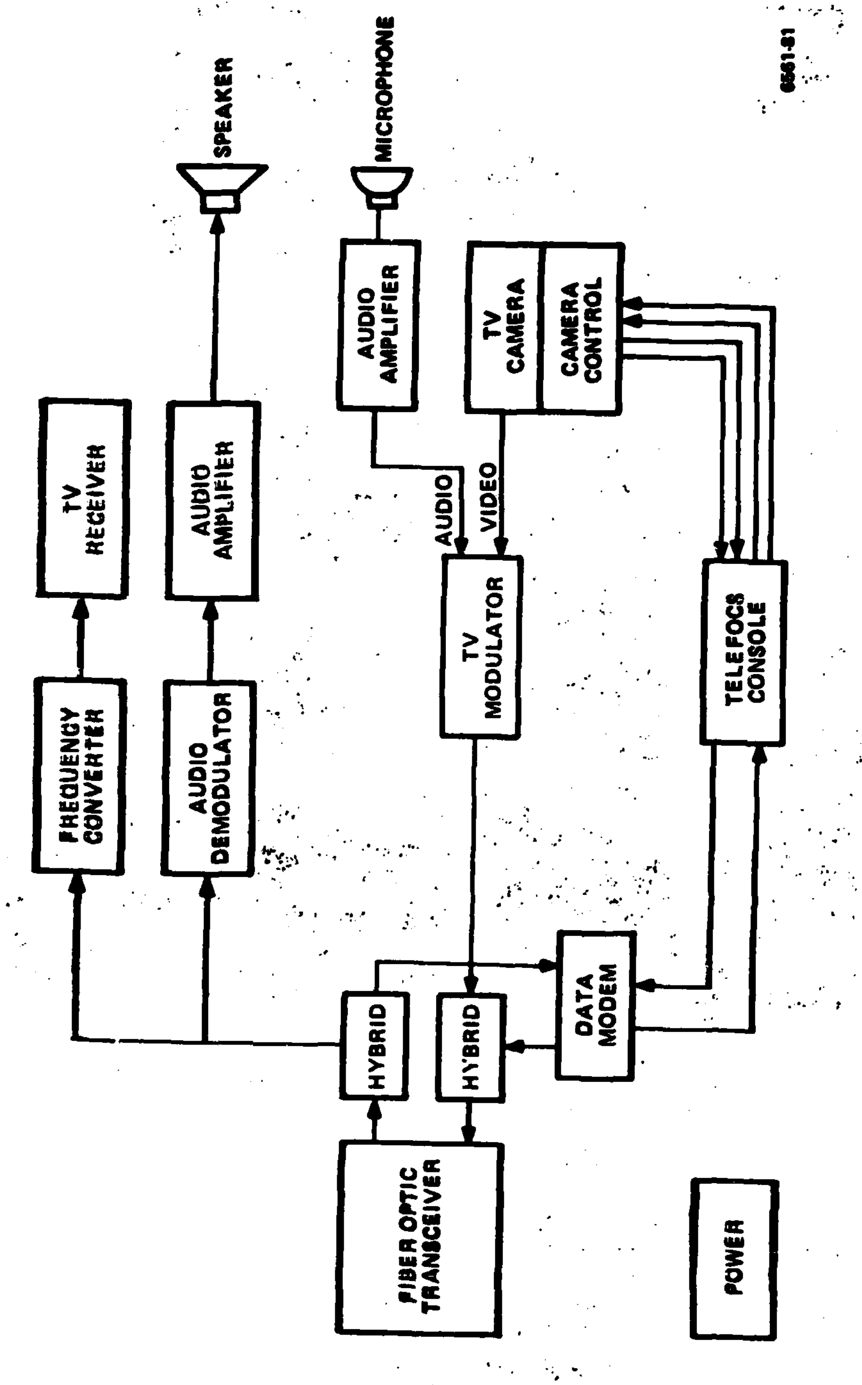


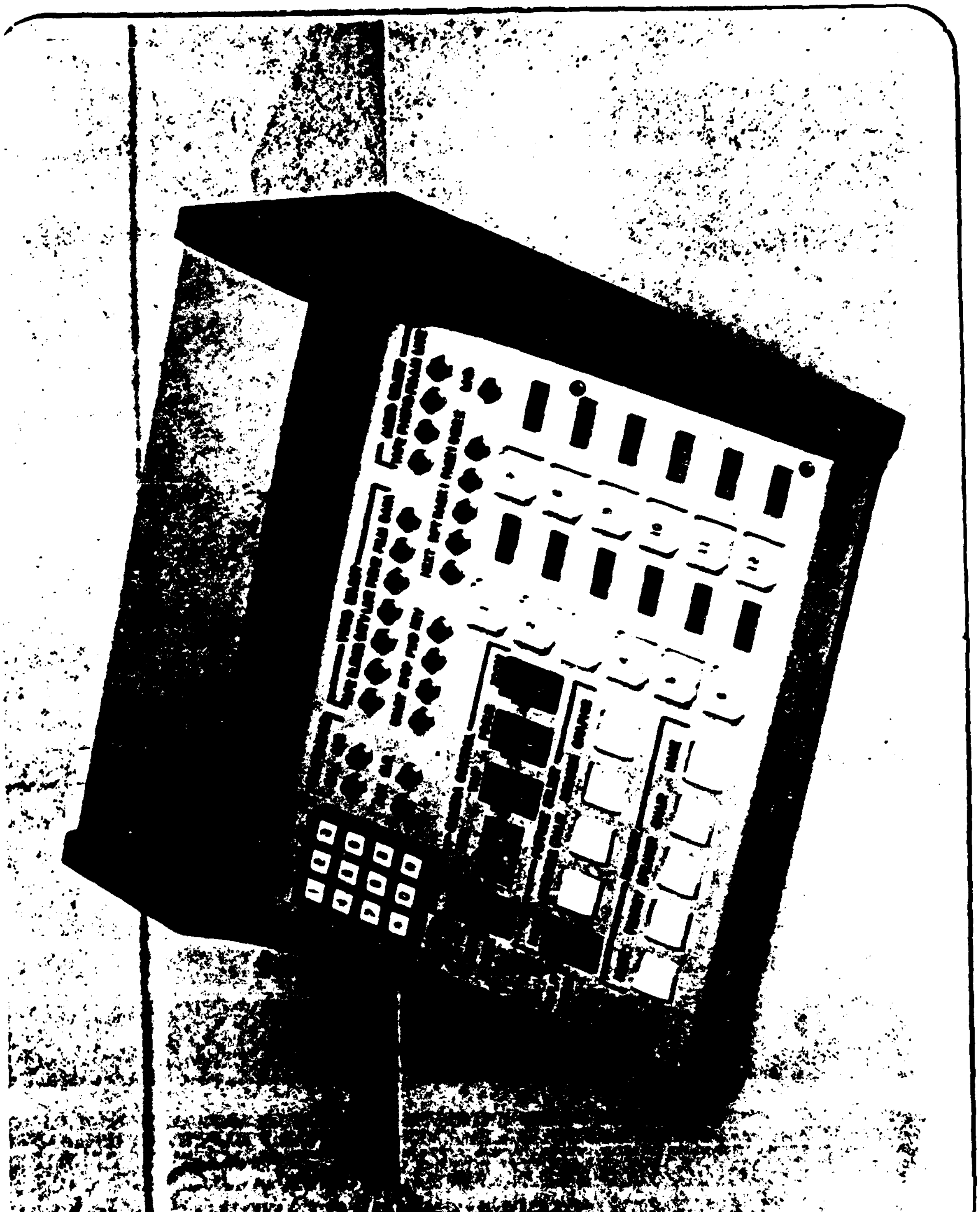


FREQUENCY PLAN



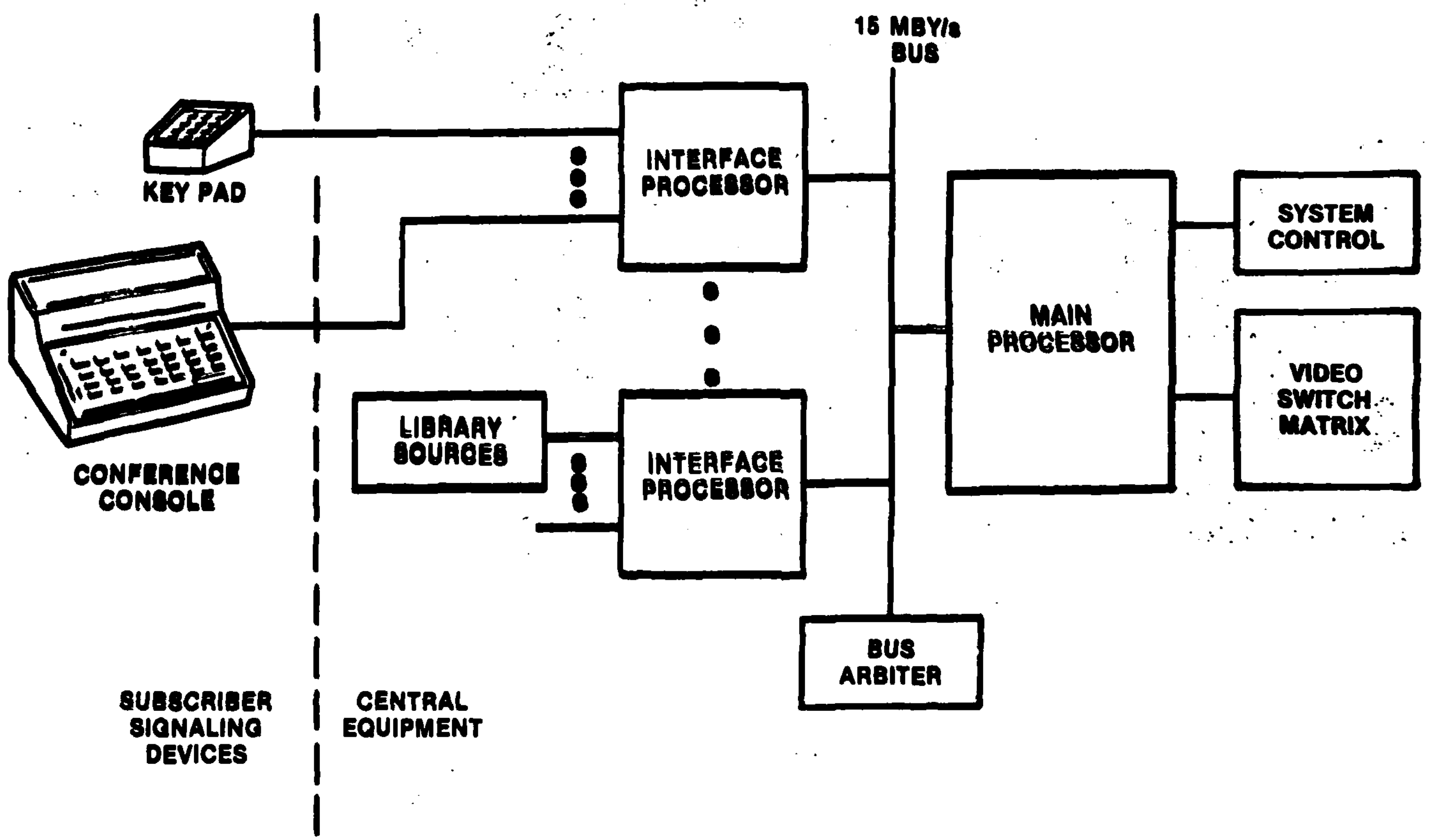



SPEAKER
MICROPHONE
6561-81
TV RECEIVER
FREQUENCY CONVERTER
AUDIO AMPLIFIER
AUDIO DEMODULATOR
AUDIO AMPLIFIER
TV CAMERA
CAMERA CONTROL
AUDIO
VIDEO
TV MODULATOR
TELEFOCS CONSOLE
DATA MODEM
HYBRID
HYBRID
FIBER OPTIC TRANSCEIVER
POWER

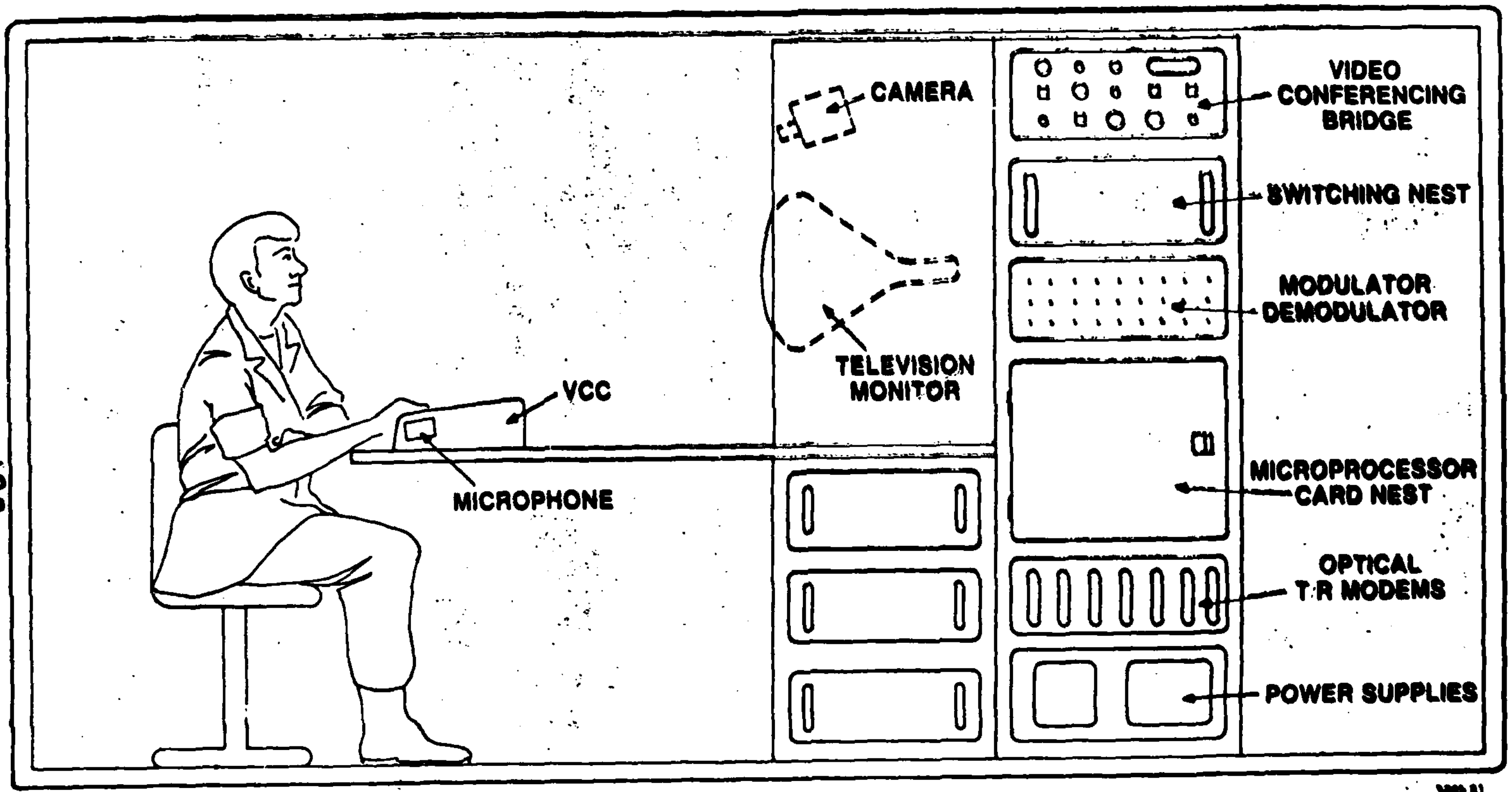


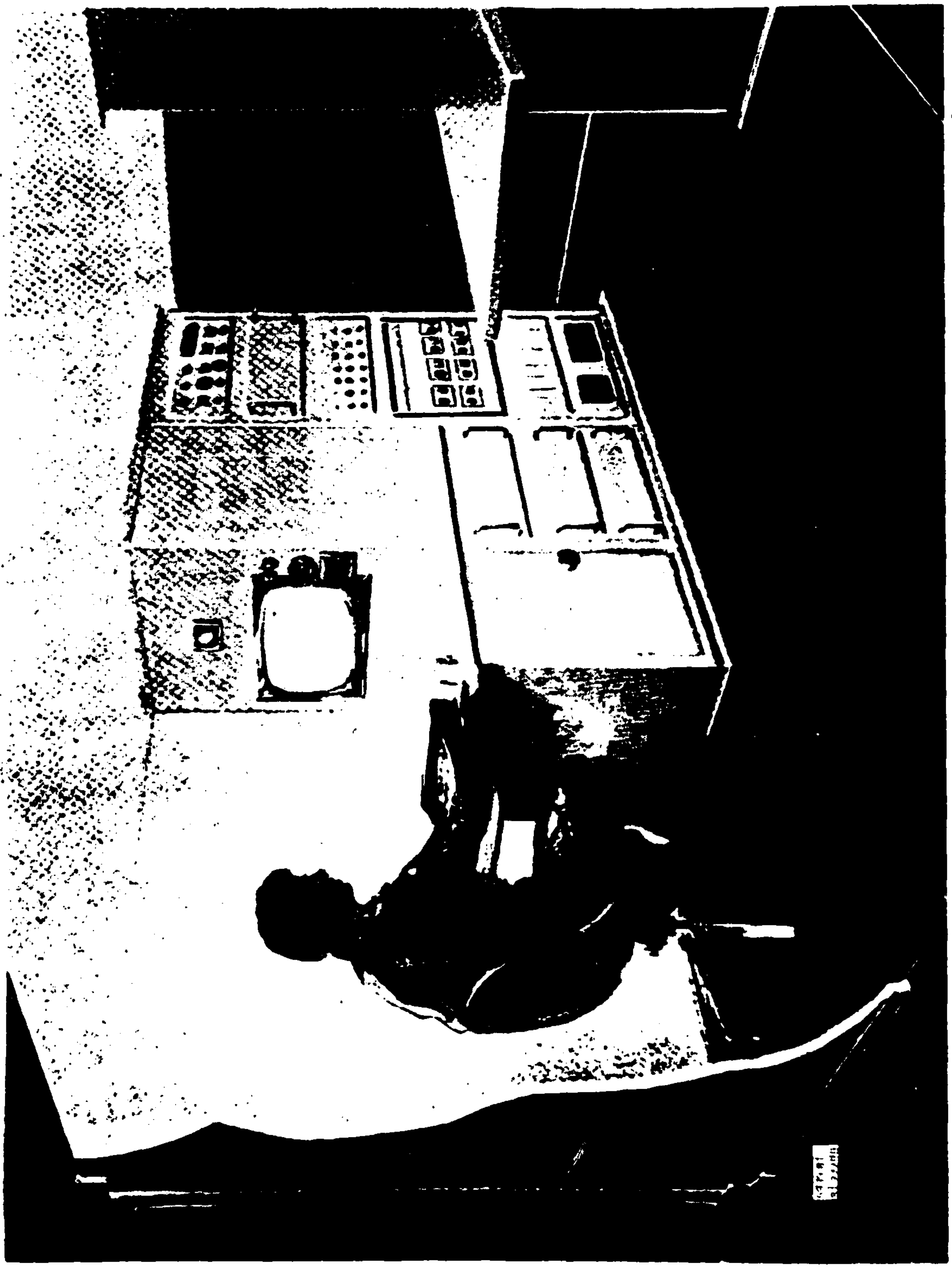

ON
RDY
ERR
BUSY
ID

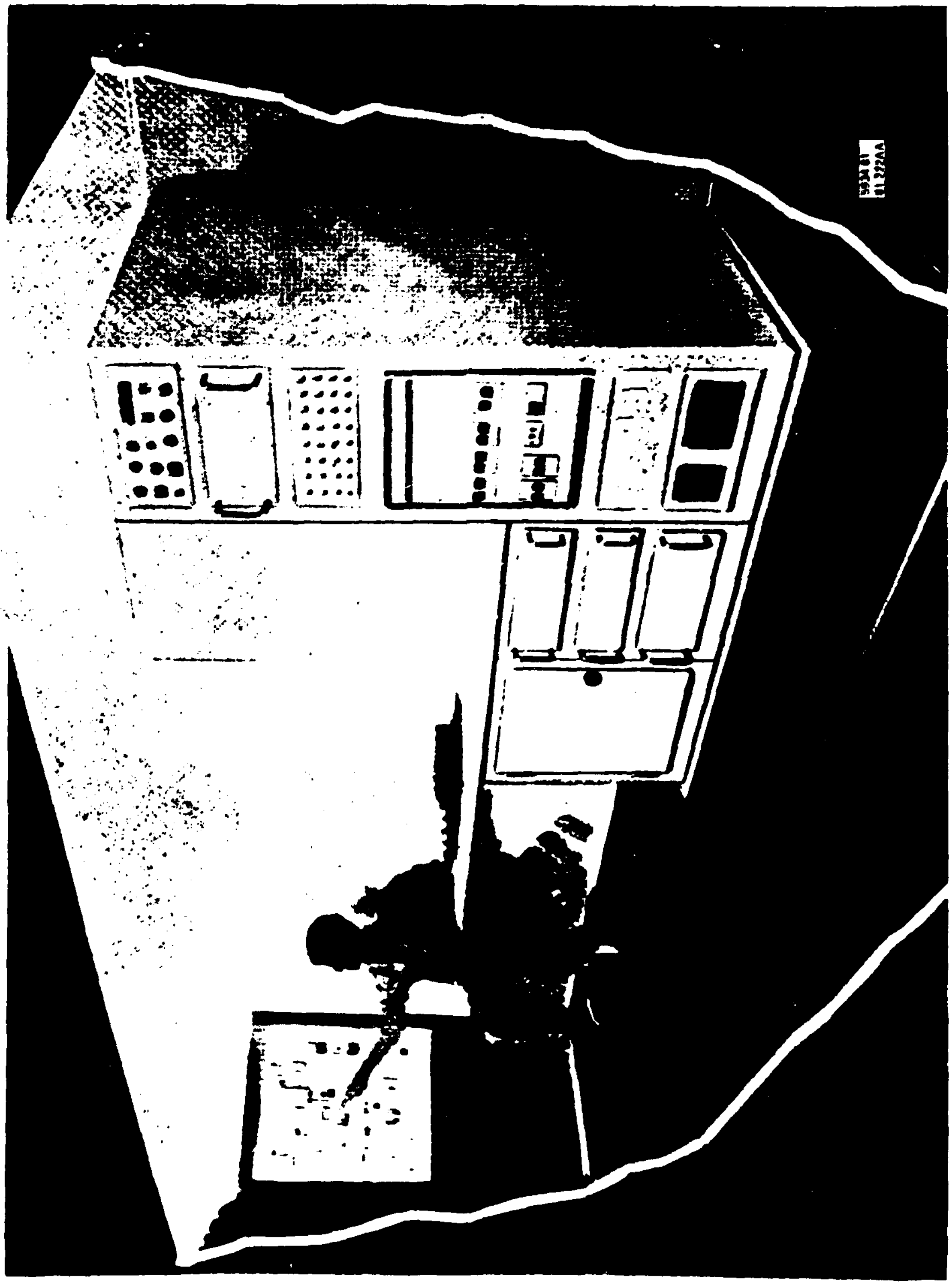
VIDEO CONTROLLER



Video Teleconferencing System – Shelter Configuration







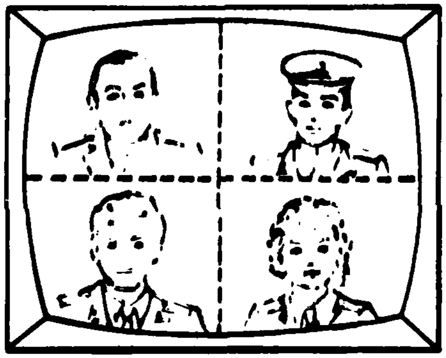
MSLS

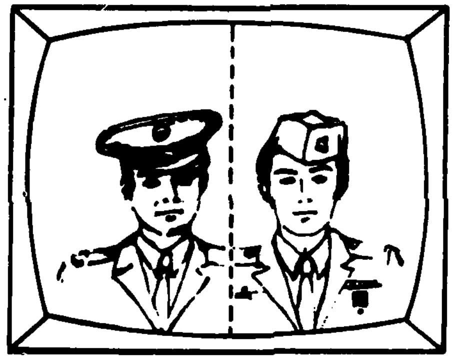
Multiservice Local System

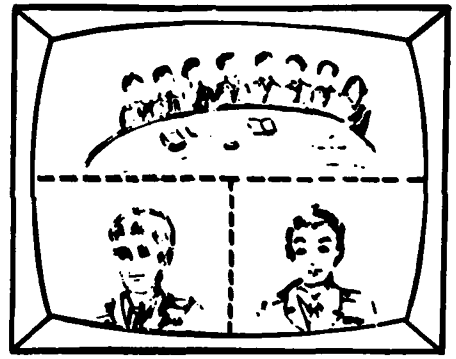
MSLS SERVICES

- Video Conferencing
- Video Distribution
- Audio Distribution
- Data Switching
- Office Services
- Voice Telephone
- Remote Control and Monitoring

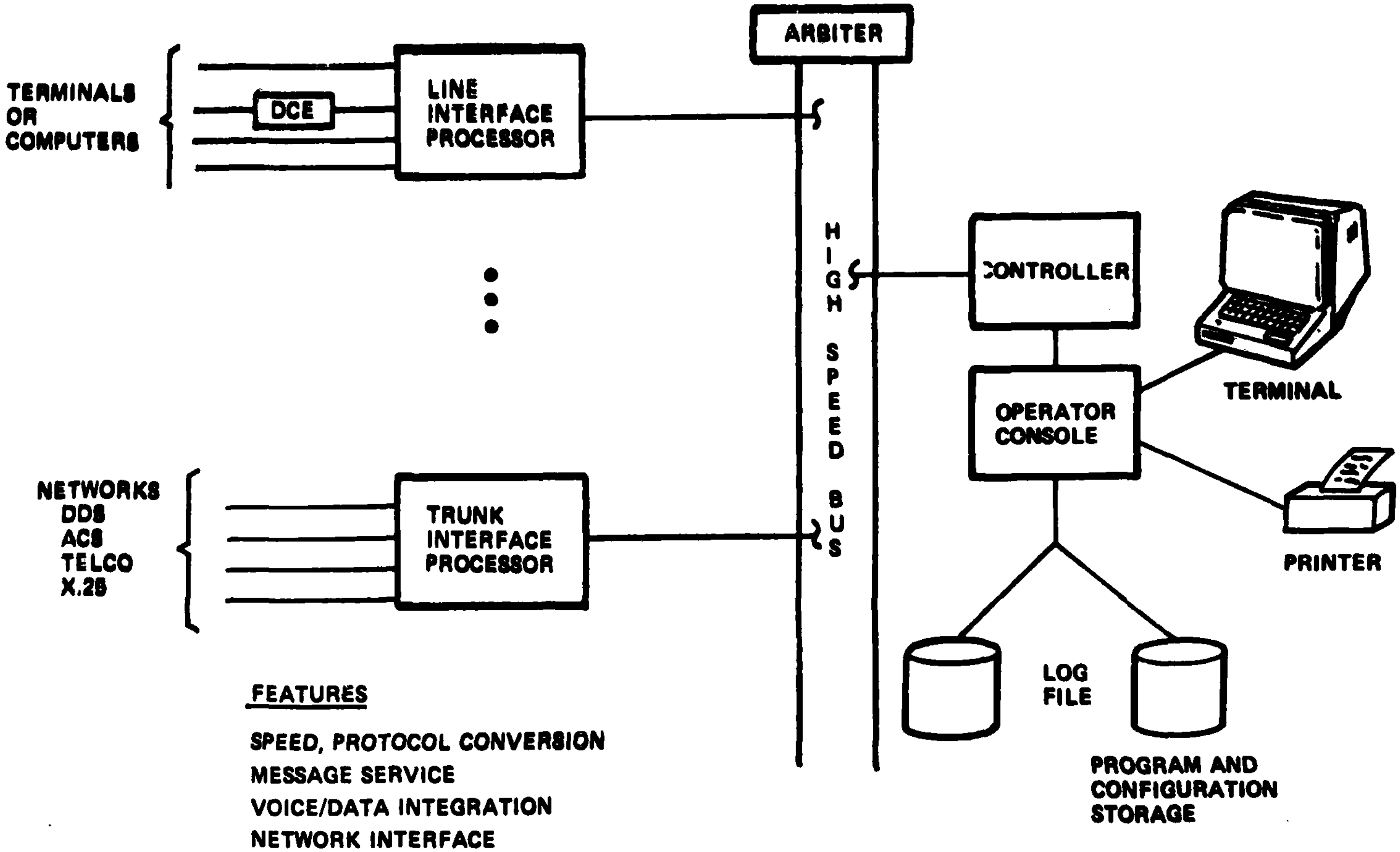
SPLIT—SCREEN PRESENTATION



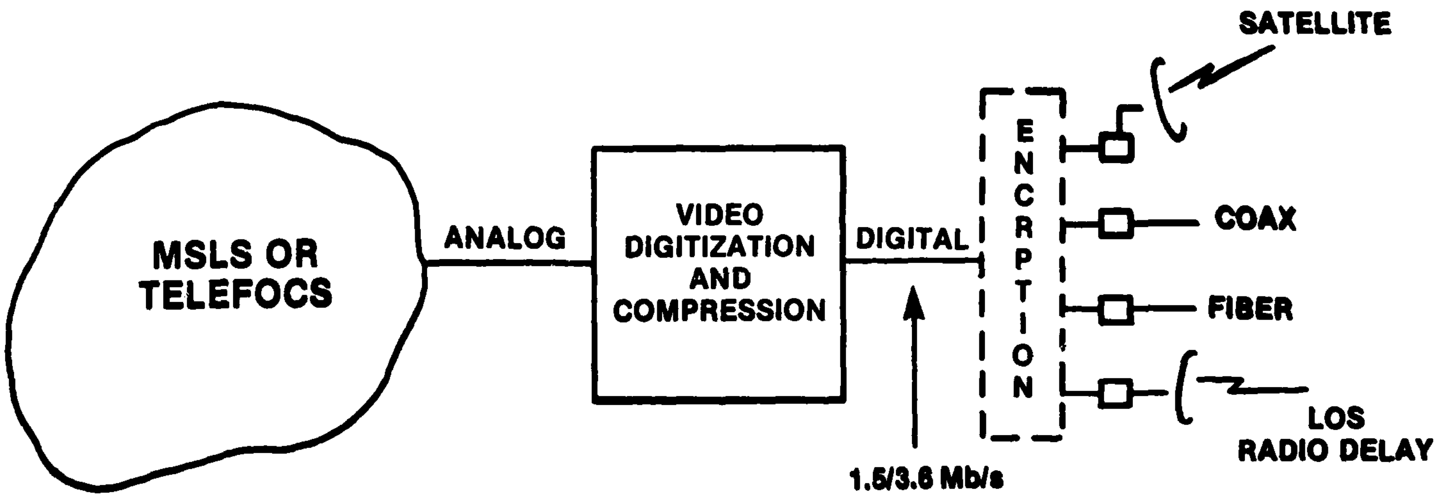


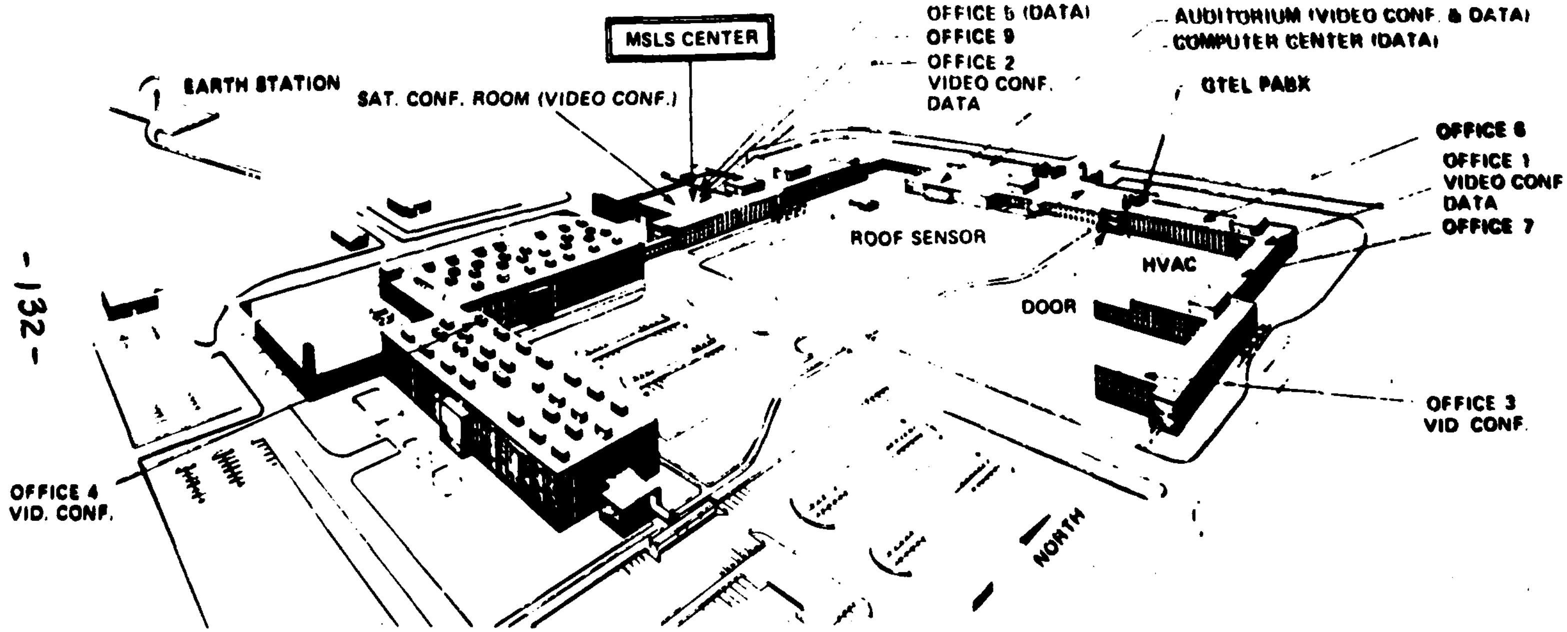


MBLB DATA SWITCH



EXTERNAL DIGITAL INTERFACE





Demonstration System Configuration

Technolgy II (0800-1000 29 Sep)

Session Chairman: Dr. Andrew Yang - RADC/ES

"Components for Optical Fiber Net," Dr. Andrew Yang and Mr. Charles Husbands, RADC and MITRE Bedford Operations

The applications and the state of development of Fiber optic components such as couplers, wavelength multiplexers, switches, repeaters, etc. will be discussed.

"Manufacturing Technology for Fused Optical Couplers," Mr. J. C. Williams and Mr. C. Villarruel, ITT EOPD and NRL

Manufacturing Technology which was developed for star and tee multimode fiber optic couplers is presented. The couplers manufactured have advanced optical and environmental performance. Over 200 couplers of 13 differend types were fabricated, optically tested and environmentally tested.

"Fiber Optic Couplers for Use in Local Area Military Networks," Mr. A. R. Nelson, AETNA Telecommunications Laboritory

A survey will be presented of fiber optic couplers suitable for use with local area military networks. The presentation will concentrate on low cost designs that are appropriate for mass production.

"Multimode Fiber Optic Switches," Mr. R. A. Soref, Sperry Research Center

Low loss fiber optic switches, especially 2x2 bypass switches are useful components in local area fiber networks. This paper will review several techniques for making such components, including the electro-mechanical, magneto-optic,and electro-optic liquid crystal techniques.

"COMPONENTS FOR FIBER OPTIC MILITARY LOCAL AREA NETWORKS"

DR A.C. YANG - RADC / ESO

DR M.D. DRAKE - MITRE

MR C.R. HUSBANDS - MITRE

TACTICAL NETWORK CHARACTERISTICS

- MOBILE
- CONNECTORIZED
- RUGGEDIZED
- REDUNDANCY
- MODULARLY EXPANDABLE
- RADIATION RESISTANT

REQUIRED COMPONENTS

- COUPLERS (TEE, STAR)
- SWITCHES
- TRANSMITTERS
- RECEIVERS
- REPEATERS
- WAVELENGTH MULTIPLEXING

TRANSMITTER CONCERNS

O MODAL NOISE

O SUPER RADIANT LED's

RECEIVER CONCERNS

- O BURSTY DATA - SYNCHRONIZATION
  D C RESTORATION
- O IDLE CHANNEL - AGC DRIFTING
- O DYNAMIC RANGE - AGC SETTLING TIME
  VESTIGAL POWER

NETWORK CONSIDERATION

- O NETWORK ARCHITECTURE
  INTERCONNECTIVITY - MINIMUM AMOUNT OF CABLE

  REDUNDANCY
- O MULTI-MEDIA – WDM

CONCLUSION

- O COMPONENTS ARE EMERGING FOR LOCAL NETWORK IMPLEMENTATION
- O HIGH COST
- O FURTHER COMPONENT DEVELOPMENT NEEDED

FUSED OPTICAL COUPLER MANUFACTURING TECHNOLOGY

J. C. WILLIAMS
ITT EOPD
ROANOKE, VA

C. VILLARRUEL
NAVAL RESEARCH LABORATORY
WASHINGTON, DC

BASED ON WORK SPONSORED BY NRL CONTRACTS

N00173-80-C-0027
N00173-80-C-0047

ITT ELECTRO-OPTICAL PRODUCTS DIVISION

FUSED OPTICAL COUPLER MANUFACTURING TECHNOLOGY

- PHASE 1
  - PROCESS DESIGN AND DOCUMENTATION
  - "PILOT" PRODUCTION
    - 24 STAR COUPLERS
    - 70 TEE AND DUPLEX COUPLERS
- PHASE 2
  - PROCESS IMPROVEMENT
    - 12 STAR COUPLERS
    - 14 TEE AND DUPLEX COUPLERS
  - "FULL SCALE" PRODUCTION
    - 40 STAR COUPLERS
    - 105 TEE AND DUPLEX COUPLERS
- PHASE 3
  - ENVIRONMENTAL TESTING
    - 30 STAR COUPLERS
    - 70 TEE AND DUPLEX COUPLERS
    - WORK STILL IN PROGRESS

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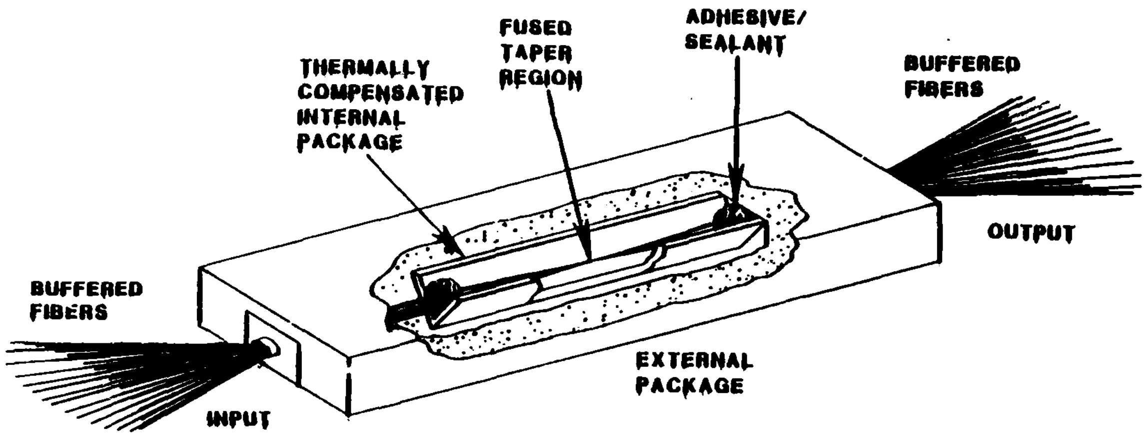
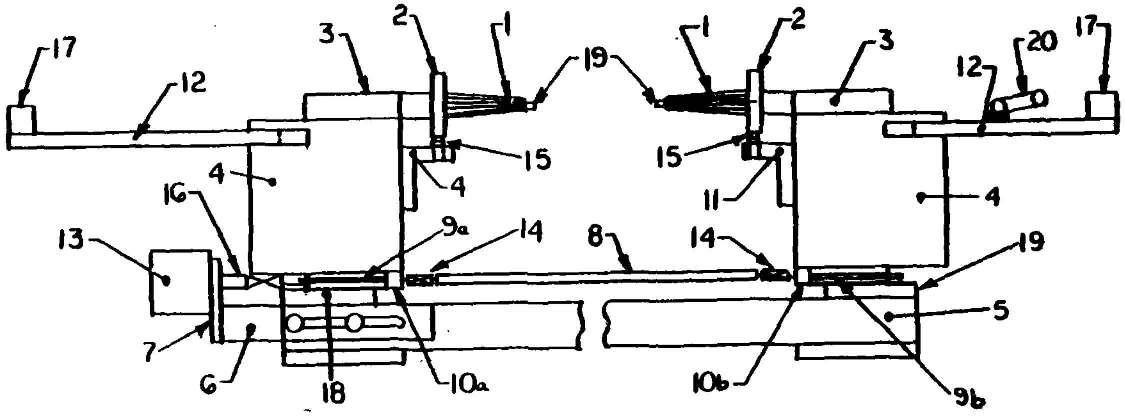


OPTICAL COUPLER PACKAGE CROSS SECTION

ELECTRO-OPTICAL
PRODUCTS DIVISION

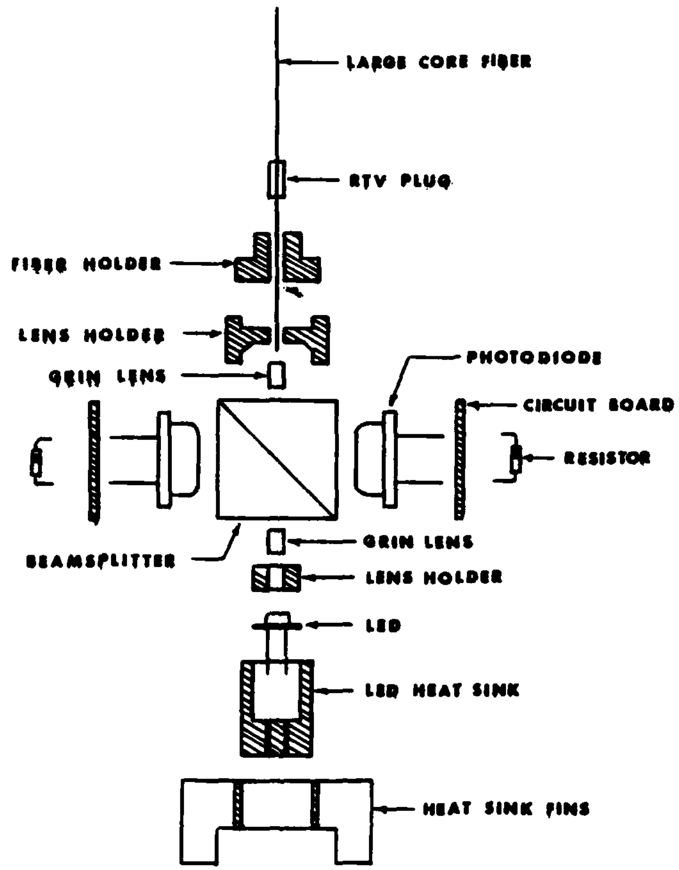


1. GUIDE SHAFT	8. DRIVE SHAFT	14. UNIVERSAL JOINTS
2. GUIDE RING	9a,b. THREADED DRIVE SHAFT	15. BALL PLUNGER
3. SUPPORT SHAFT	10a,b. THREADED STOP	16. FLEXIBLE SHAFT
4. SUPPORT BRACKET	11. BALL PLUNGER MOUNT	17. FELT CLAMP
5. BASE	12. EXTENSION BRACKET	18. TRANSLATION STAGE
6. MOTOR MOUNT SUPPORT	13. DC MOTOR	19. GUIDE SHAFT ADAPTORS
		20. TENSION BAR

ROTARY FUSION STATION
ASSEMBLY DRAWING

ELECTRO-OPTICAL PRODUCTS DIVISION

BEAMSPLITTER DETECTION - INJECTION ASSEMBLY



ELECTRO-OPTICAL PRODUCTS DIVISION

FUSED OPTICAL COUPLER MANUFACTURING TECHNOLOGY ADVANCES

- FABRICATION TECHNOLOGY
  - FIXED, WIDE TORCH FOR LOW LOSS
  - TENSION CONTROL FOR UNIFORMITY
  - PUSH-PULL AND SCRIBE AND BREAK TECHNIQUES FOR UNIFORMITY
- MEASUREMENT TECHNOLOGY
  - INSERTION LOSS MATRIX MEASUREMENTS
  - INJECTION - DETECTION STATIONS
- PACKAGING TECHNOLOGY
  - THERMALLY MATCHED INTERNAL PACKAGE

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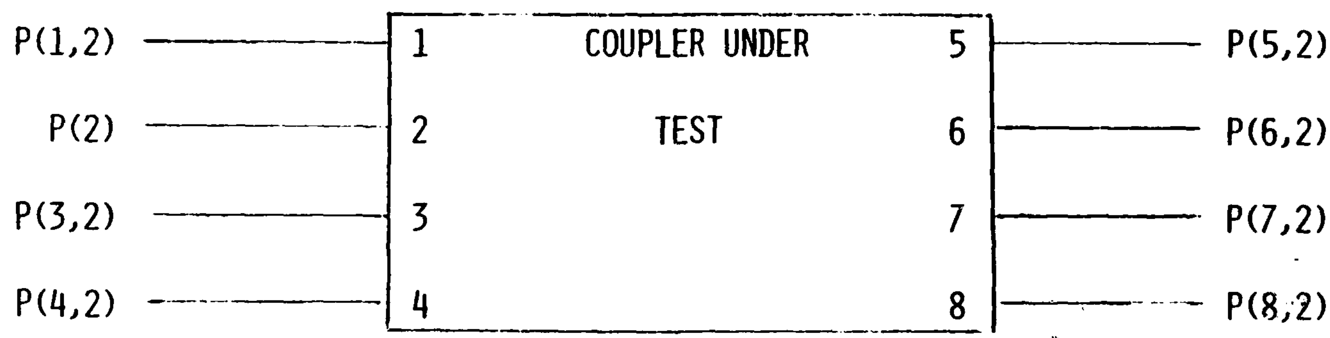
OPTICAL COUPLER SPECIFICATIONS

- INSERTION LOSS
- UNIFORMITY
- EXCESS LOSS
- BACKSCATTER
- MODAL UNIFORMITY

ITT ELECTRO-OPTICAL PRODUCTS DIVISION

OPTICAL COUPLER TESTING DEFINITIONS



P(J) = INPUT POWER LEVEL AT PORT J

P(I,J) = POWER AT OUTPUT PORT I COUPLED FROM INPUT PORT J

ITT ELECTRO-OPTICAL PRODUCTS DIVISION

OPTICAL COUPLER INSERTION LOSS

IL (I, J) = INSERTION LOSS TO OUTPUT I FROM INPUT J AND COMPUTED FROM:

$$IL\ (I,\ J) = -10\ \log \frac{P\ (I,\ J)}{P\ (J)} \qquad \text{(dB)}$$

WHERE P (I, J) = POWER AT OUTPUT PORT I
COUPLED FROM INPUT PORT J

P (J) = INPUT POWER LEVEL AT PORT J

ELECTRO-OPTICAL PRODUCTS DIVISION

OPTICAL COUPLER EXCESS LOSS

$$EL(I, J) = IL(I, J) - 10 \log M$$

WHERE M = NUMBER OF OUTPUT PORTS

ELECTRO-OPTICAL PRODUCTS DIVISION

OPTICAL COUPLER UNIFORMITY

- OSR = OPTICAL SIGNAL RANGE COMPUTED AS

$$OSR = MAX\ \left| IL\ (I,\ J) \right| - MIN\ \left| IL\ (I,\ J) \right| \qquad (dB)$$

- U (J) = UNIFORMITY OF ALL PORTS FOR INPUT J COMPUTED AS:

$$U\ (J) = \frac{MAX\ P\ (I,\ J) - MIN\ P\ (I,J)}{MAX\ P\ (I,\ J)} \qquad (\%)$$

WHERE THE MAXIMA AND MINIMA CONSIDER ALL OUTPUTS, I

ELECTRO-OPTICAL PRODUCTS DIVISION

2 X 2 COUPLER PERFORMANCE MATRIX

INSERTION LOSS IN dB

OUTPUT PORT I	INPUT J 1	2	3	4	A(I)
1	*	*	3.5	4.1	3.8
2	*	*	3.8	3.6	3.7
3	3.6	4.0	*	*	3.8
4	3.9	3.6	*	*	3.8
U(J)	8%	8%	7%	12%	
					0.8
E(J)	0.7	0.8	0.6	0.8	

U(J) = UNIFORMITY

E(J) = TOTAL EXCESS LOSS

A(I) = AVERAGE INSERTION LOSS

* = BACKSCATTER ELEMENT NOT MEASURED

ELECTRO-OPTICAL PRODUCTS DIVISION

Coupler Insertion Loss Matrix Before Modification of Mixing Region.

16-Port (8 x 8) Transmission Coupler
Coupler Type T-7014
Coupler Number 8115-0004
Fiber id 810114-12

Insertion Loss Matrix (dB)

Output Port I	Input J: 1	2	3	4	9	10	11	12
1					9.4	10.5	10.1	10.6
2		Backscatter			11.0	9.8	10.5	10.9
3		Elements			10.9	10.6	9.9	10.8
4					10.7	10.5	10.2	9.8
5					10.9	10.9	10.5	10.9
6					10.5	10.5	10.2	10.6
7					10.7	10.7	10.4	10.8
8					11.0	10.8	10.5	10.8
9	9.5	10.8	10.9	10.4				
10	10.8	9.8	10.7	10.4				
11	10.5	10.5	10.2	10.1		Backscatter		
12	10.8	10.9	10.9	9.6		Elements		
13	10.6	10.7	10.7	10.3				
14	10.5	10.7	10.7	10.3				
15	10.6	10.8	10.8	10.4				
16	10.4	10.5	10.5	9.9				
Uniformity Factor	25%	22%	15%	17%	31%	21%	14%	23%

ELECTRO-OPTICAL PRODUCTS DIVISION

Coupler Insertion Loss Matrix After Modification of Mixing Region To Improve Uniformity.

16-Port (8 x 8) Transmission Coupler
Coupler Type T-7014
Coupler Number 8115-0004
Fiber id 810114-12

Insertion Loss Matrix (dB)

Output Port I	Input J							
	1	2	3	4	9	10	11	12
1	Backscatter Elements				10.4	10.3	10.1	10.5
2					10.9	10.6	10.4	10.8
3					10.9	10.6	10.2	10.8
4					10.7	10.4	10.2	10.5
5					10.7	10.8	10.6	10.9
6					10.5	10.3	10.1	10.5
7					10.7	10.5	10.3	10.7
8					11.0	10.8	10.6	10.8
9	10.5	10.8	10.9	10.4	Backscatter Elements			
10	10.6	10.6	10.7	10.3				
11	10.4	10.4	10.5	10.1				
12	10.7	10.8	10.9	10.4				
13	10.5	10.6	10.7	10.2				
14	10.4	10.5	10.7	10.2				
15	10.5	10.7	10.8	10.4				
16	10.3	10.4	10.5	10.0				
Uniformity Factor	8%	8%	9%	3%	11%	10%	10%	9%

ELECTRO-OPTICAL
PRODUCTS DIVISION

8 PORT REFLECTION STAR PERFORMANCE MATRIX

INSERTION THROUGHPUT IN dB

OUTPUT PORT I	INPUT J 1	2	3	4	5	6	7	8
1	*	-11.2	-11.5	-11.1	-11.5	-11.5	-10.9	-11.7
2	-11.3	*	-11.4	-11.1	-11.5	-11.4	-10.9	-11.7
3	-11.4	-11.4	*	-11.2	-11.7	-11.7	-10.8	-11.8
4	-11.2	-11.1	-11.3	*	-11.4	-11.4	-10.8	-11.4
5	-11.6	-11.6	-11.8	-11.5	*	-11.8	-11.3	-12.0
6	-11.6	-11.4	-11.7	-11.4	-11.8	*	-11.2	-11.9
7	-11.2	-11.1	-11.1	-11.0	-11.4	-11.3	*	-11.5
8	-11.5	-11.5	-11.7	-11.3	-11.7	-11.8	-11.2	*
U(J)	9%	11%	13%	10%	8%	10%	11%	13%
P(J)	9%	11%	9%	10%	8%	10%	11%	11%
A(J)	-11.4	-11.3	-11.5	-11.2	-11.6	-11.6	-11.0	-11.7
MIN(J)	-11.6	-11.6	-11.8	-11.5	-11.8	-11.8	-11.3	-12.0
MAX(J)	-11.2	-11.1	-11.1	-11.0	-11.4	-11.3	-10.8	-11.4

ELECTRO-OPTICAL PRODUCTS DIVISION

16 PORT TRANSMISSION STAR PERFORMANCE MATRIX

INSERTION THROUGHPUT IN dB

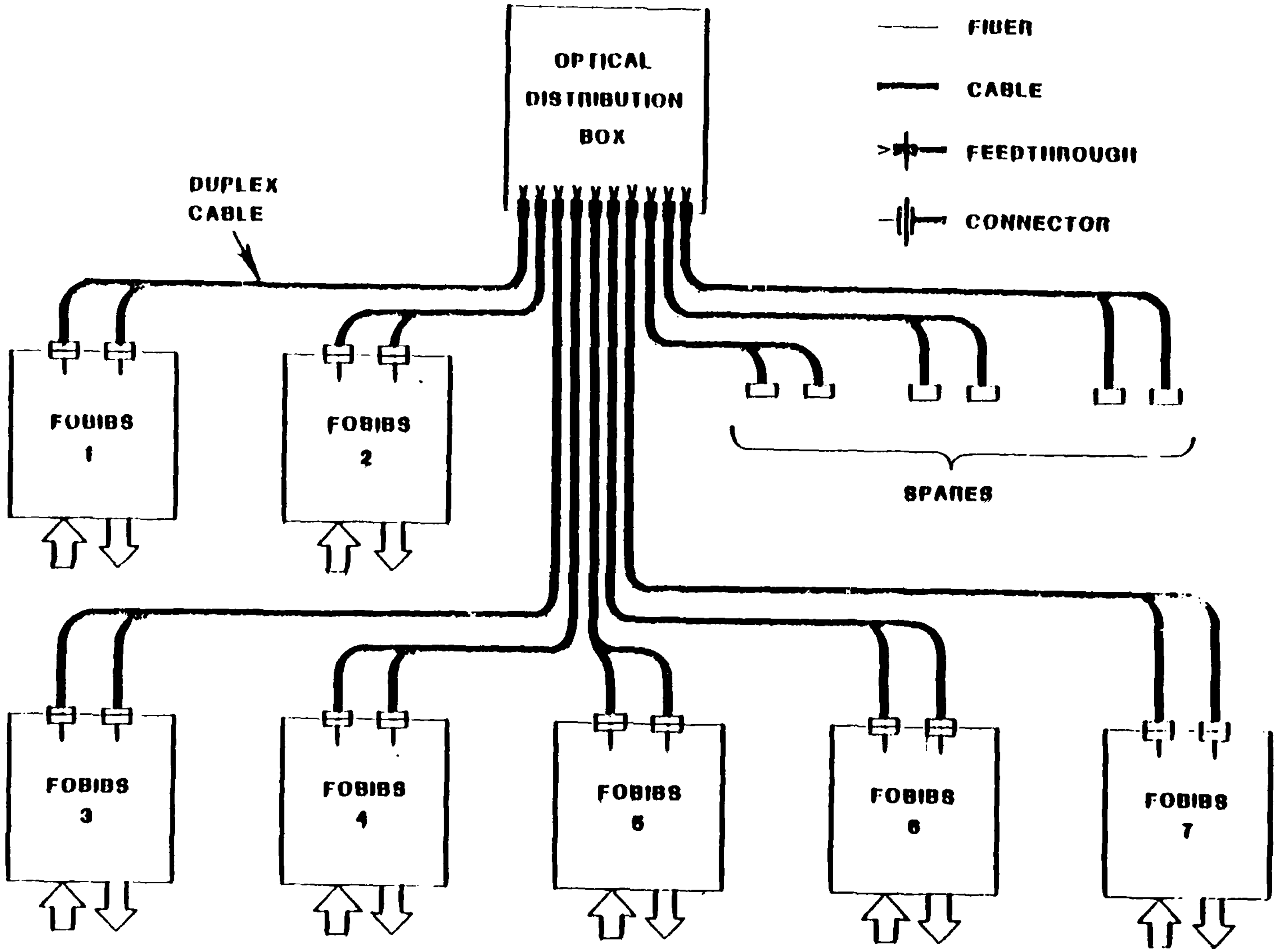
OUTPUT PORT I	INPUT J 17	18	19	20	21	22	23	24	A[I]
1	-13.3	-15.8	-15.6	-15.8	-15.3	-15.3	-15.6	-15.4	-15.2
2	-14.8	-13.9	-15.5	-15.7	-15.2	-15.0	-15.5	-15.3	-15.1
3	-15.0	-15.6	-14.3	-15.8	-15.4	-15.3	-15.7	-15.5	-15.3
4	-14.3	-14.8	-14.9	-14.3	-14.6	-14.5	-15.0	-14.8	-14.6
5	-14.1	-14.7	-14.7	-14.9	-13.5	-14.3	-14.8	-14.6	-14.4
6	-14.8	-15.4	-15.5	-15.6	-15.2	-14.6	-15.5	-15.3	-15.2
7	-14.6	-15.1	-15.2	-15.4	-14.9	-14.8	-14.4	-15.1	-14.9
8	-14.3	-14.8	-14.9	-15.1	-14.6	-14.5	-14.9	-14.3	-14.7
9	-14.5	-15.1	-15.2	-15.3	-14.9	-14.8	-15.2	-15.0	-15.0
10	-13.8	-14.5	-14.5	-14.6	-14.2	-14.0	-14.5	-14.3	-14.3
11	-13.6	-14.1	-14.2	-14.4	-13.9	-13.8	-14.3	-14.1	-14.1
12	-14.1	-14.7	-14.7	-14.9	-14.4	-14.3	-14.8	-14.6	-14.5
13	-14.1	-14.7	-14.8	-15.0	-14.5	-14.4	-14.8	-14.7	-14.6
14	-13.4	-14.0	-14.1	-14.2	-13.8	-13.6	-14.1	-13.9	-13.9
15	-14.2	-14.8	-14.8	-15.0	-14.5	-14.4	-14.9	-14.7	-14.6
16	-14.3	-14.8	-15.0	-15.0	-14.7	-14.5	-15.0	-14.9	-14.8
U[J]	33%	36%	29%	31%	35%	32%	31%	31%	
P[J]	31%	35%	29%	31%	31%	32%	31%	31%	
A[J]	-14.2	-14.8	-14.9	-15.0	-14.6	-14.5	-14.9	-14.8	-14.7
E[J]	-2.1	-2.7	-2.8	-3.0	-2.5	-2.4	-2.9	-2.7	-2.6
MIN[J]	-15.0	-15.8	-15.6	-15.8	-15.4	-15.3	-15.7	-15.5	
MAX[J]	-13.3	-13.9	-14.1	-14.2	-13.5	-13.6	-14.1	-13.9	

ELECTRO-OPTICAL PRODUCTS DIVISION

SYSTEM DESIGN EXAMPLE

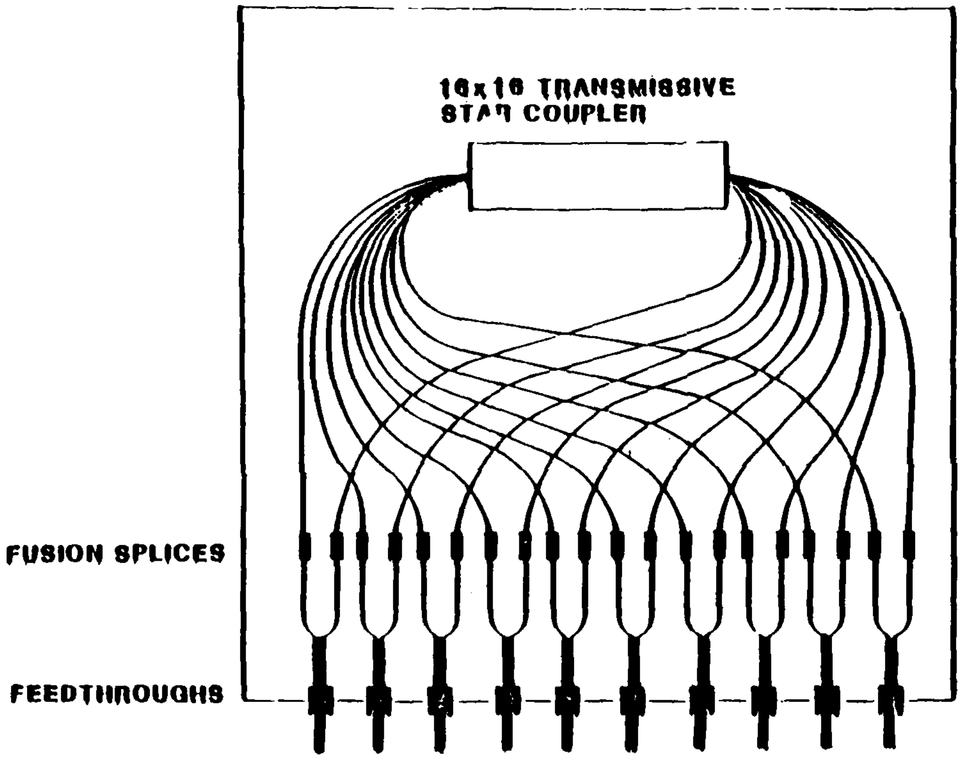
- 100 MB/s DATA BUS
- STAR TYPOLOGY
- TRANSMISSION TYPE 16 x 16 COUPLER

ELECTRO-OPTICAL PRODUCTS DIVISION



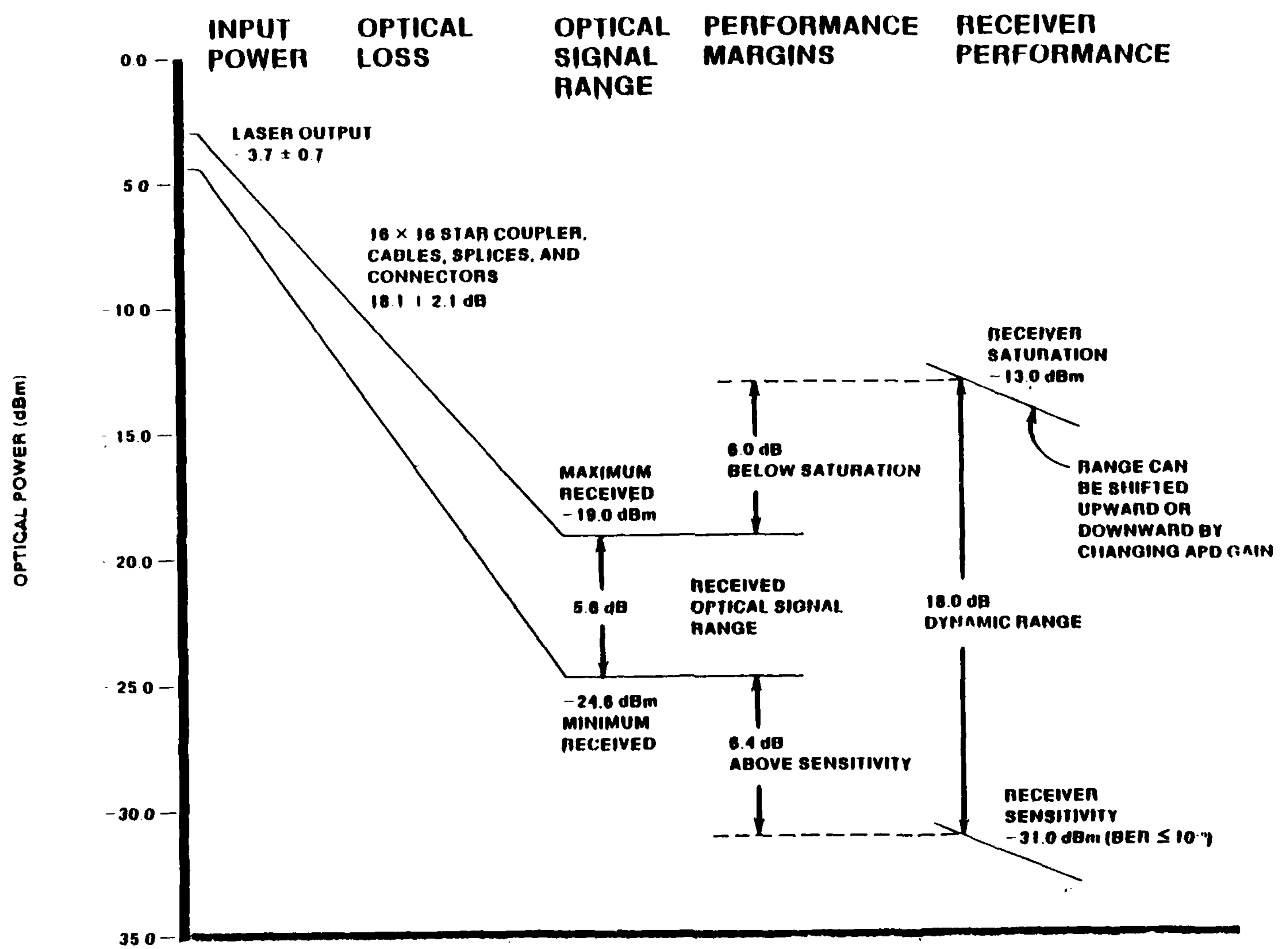
FIBER OPTIC DATA BUS

ITT ELECTRO-OPTICAL PRODUCTS DIVISION



OPTICAL DISTRIBUTION BOX

ELECTRO-OPTICAL PRODUCTS DIVISION



ITT ELECTRO-OPTICAL PRODUCTS DIVISION

102 15590

CONCLUSIONS

- COUPLERS ARE AVAILABLE FOR A WIDE VARIETY OF SYSTEMS
- OPTICAL PERFORMANCE OF THE COUPLERS IS EXCELLENT
- ENVIRONMENTAL PERFORMANCE OF THE COUPLERS IS GOOD

ITT ELECTRO-OPTICAL PRODUCTS DIVISION

Biography

Dr. Arthur R. Nelson is currently manager of the Fiber Optic Component Group at Aetna Telecommunications Laboratories in Westborough, Massachusetts. Responsibilities include the development of fiber optic couplers and sensors suitable for economical mass production. Previously, Dr. Nelson was a member of the technical staff at the Sperry Research Center in Sudbury, Massachusetts, working on fiber optic switches, sensors and multiplexing systems. From 1977 to 1979, he was supervisor of a fiber optic coupler group at ITT in Roanoke, Virginia. Dr. Nelson received the Ph.D. in Physics from Rensselaer Polytechnic Institute in 1973 and the M.S. in Physics from Cornell University in 1969.

FIBER OPTIC COUPLERS FOR USE IN LOCAL AREA MILITARY NETWORKS

A.R. Nelson
Aetna Telecommunications Laboratories

Summary

A survey is presented of fiber optic couplers for use in local area military networks. In particular, a new active coupler is described that conveniently incorporates a source and detector in the coupler itself. This new coupler is low cost, extremely efficient, and easily mass produced. In addition,, the active coupler eliminates the need for several splices and/or connectors in a typical system as compared with present couplers.

FIBER OPTIC COUPLERS FOR USE IN
LOCAL AREA MILITARY NETWORKS

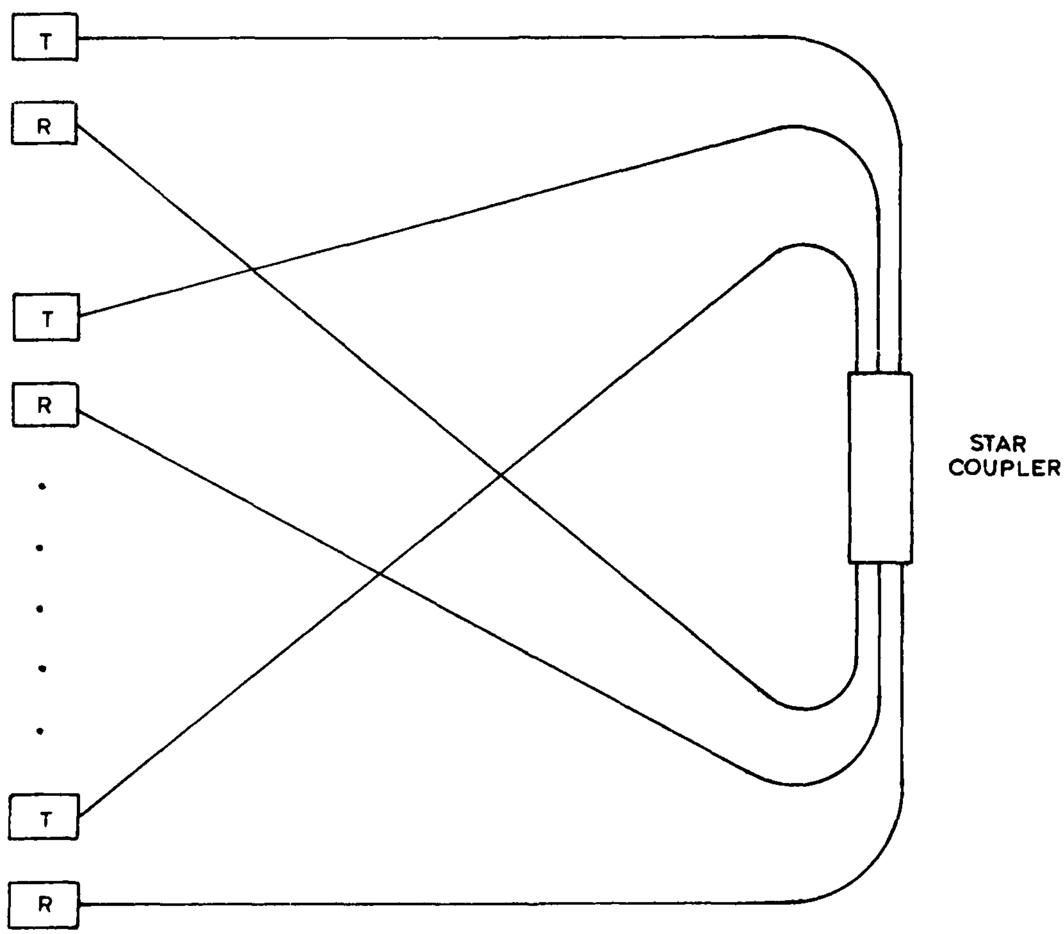
ARTHUR. R. NELSON
AETNA TELECOMMUNICATIONS LABORATORIES
WESTBOROUGH, MA 01581

FIBER OPTIC COUPLERS FOR USE IN
LOCAL AREA MILITARY NETWORKS

COUPLER TYPES

- STAR COUPLERS
- DIRECTIONAL COUPLERS
- BIDIRECTIONAL COUPLERS
- WDM COUPLERS
- SWITCHES

STAR COUPLERS - -PARALLEL CONFIGURATION NETWORK



TRANSMISSION STAR

AETNA TELECOMMUNICATIONS
LABORATORIES

STAR COUPLERS -- FABRICATION METHODS

FUSED BICONICAL TAPER

- FIBERS FUSED AND TAPERED
- LOW LOSSES, GOOD UNIFORMITY
- DOES NOT LEND ITSELF WELL TO MASS PRODUCTION
- LONG TERM RELIABILITY IS NOT KNOWN

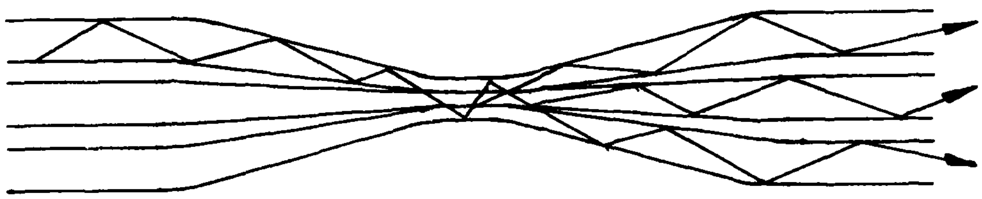
MIXER ROD APPROACH

- FIBERS ATTACHED TO A SEPARATE MIXING REGION
- RELATIVELY HIGHER LOSS, GOOD UNIFORMITY
- MODERATELY DIFFICULT TO MASS PRODUCE

DIFFUSED COUPLERS

- NEWLY DEVELOPED TECHNIQUES
- HIGH LOSS
- EXCELLENT FOR MASS PRODUCTION

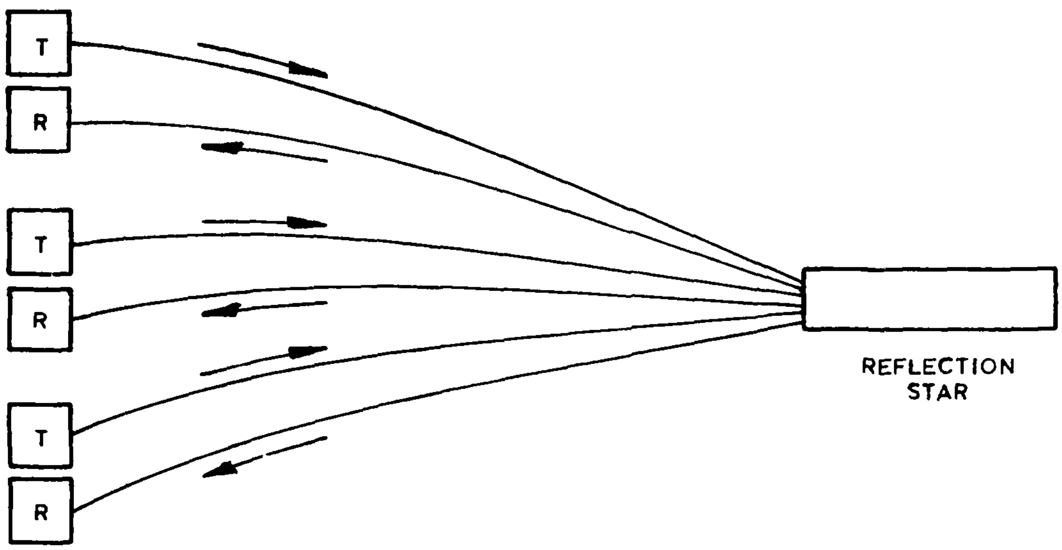
FUSED TRANSMISSION STAR COUPLER



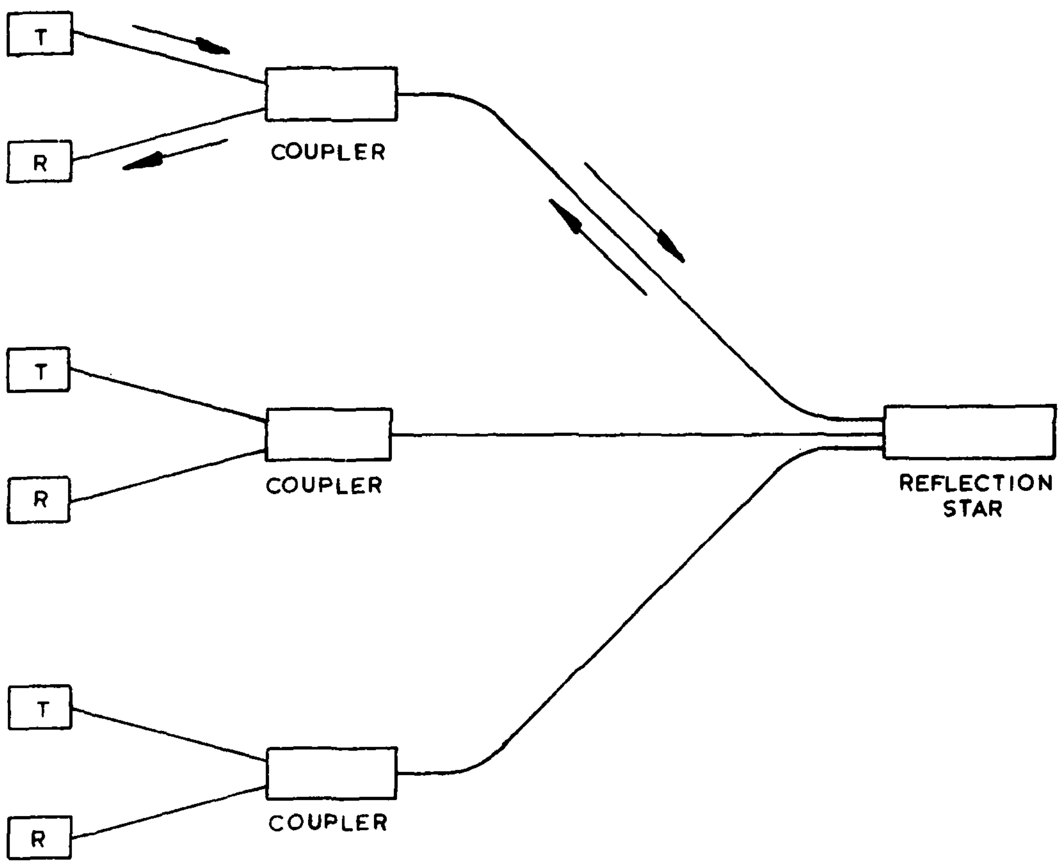
TYPICAL PERFORMANCE

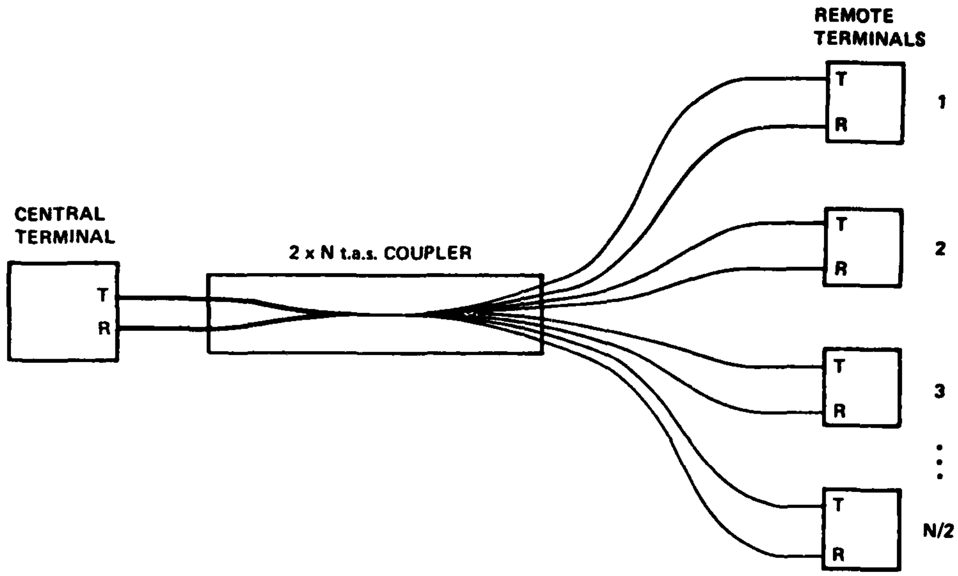
NO. OF FIBERS	2 TO100
EXCESS LOSS	~1dB
UNIFORMITY	±10%
DIRECTIVITY	40dB MIN.

REFLECTION STAR COUPLER

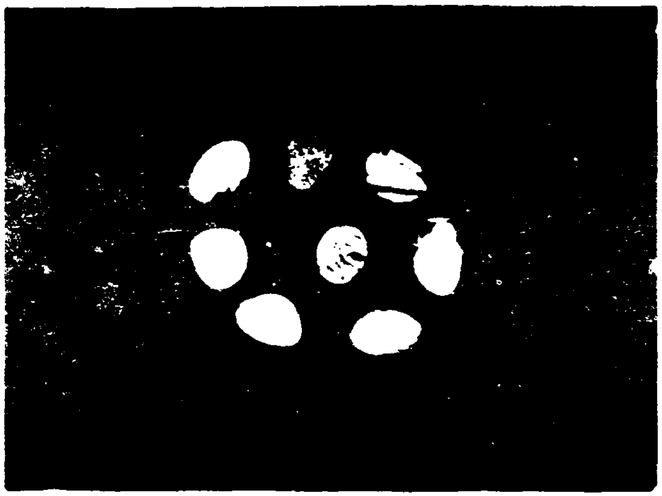


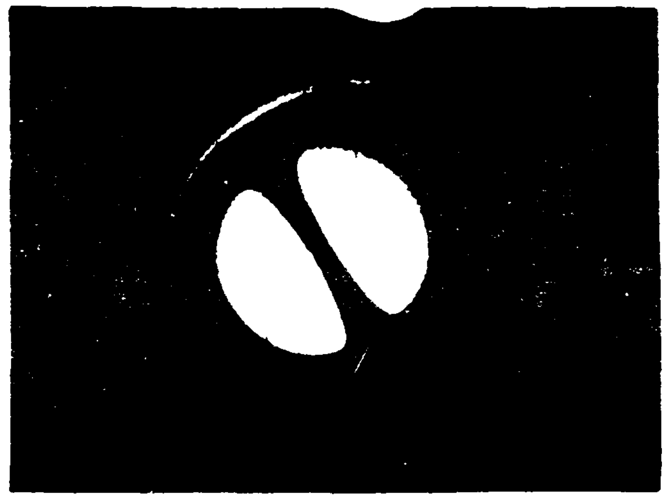
STAR WITH BIDIRECTIONAL TRANSMISSION





F.O. system using 2 x N t.a.s. coupler.





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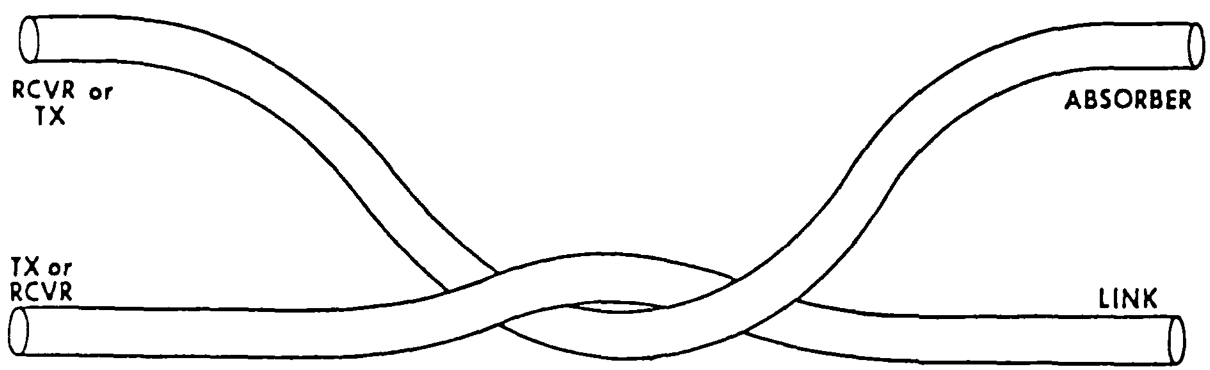
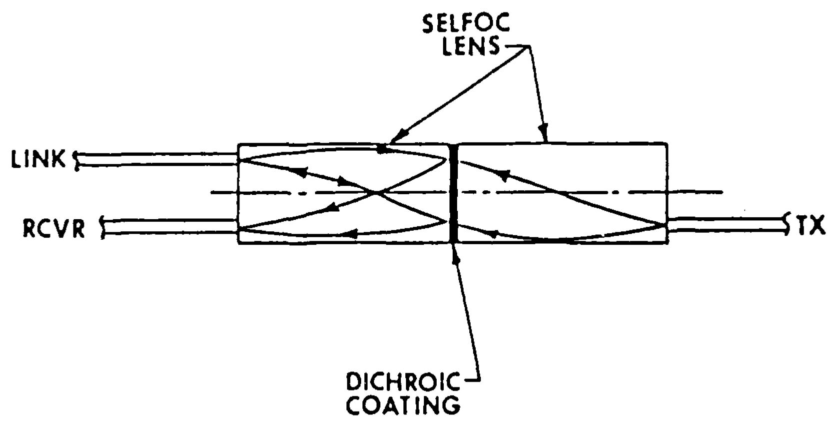
THREE PORT COUPLER TYPES

- FUSED BICONICAL TAPER
- FIBER BEAMSPLITTER
- LENSED BEAMSPLITTER
- "ACTIVE" COUPLER
  INCORPORATING Tx AND Rc IN
  THE COUPLER ITSELF



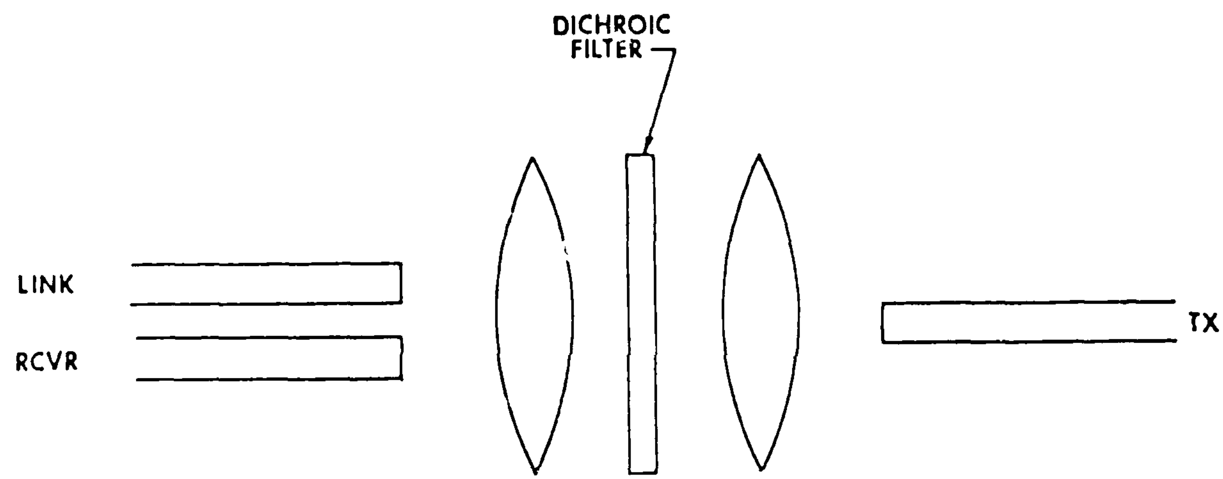
FUSED BICONICAL TAPER

AETNA TELECOMMUNICATIONS
LABORATORIES



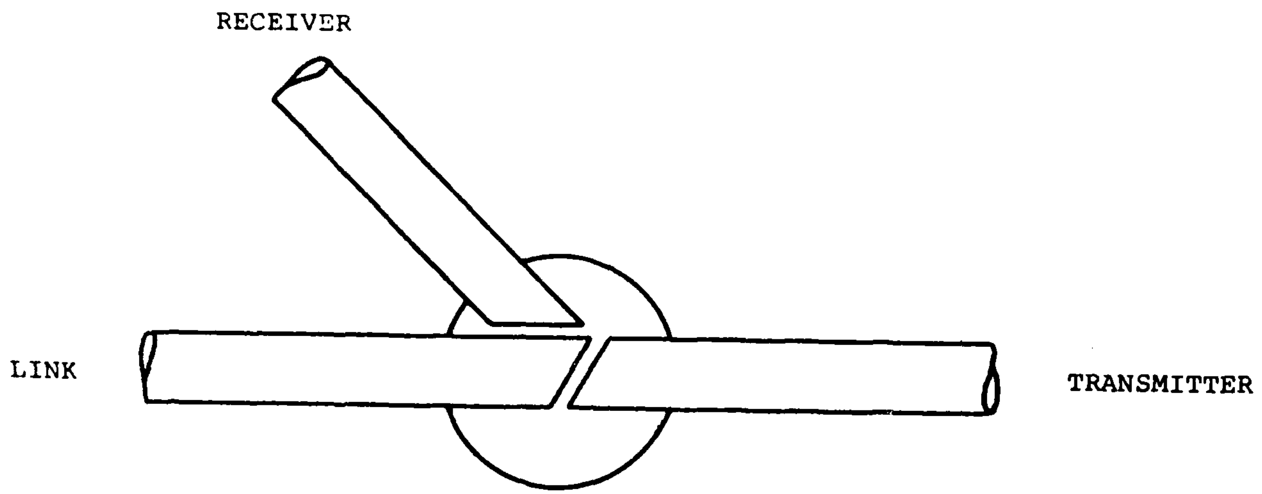
BI-DIRECTIONAL COUPLER USING SELFOC® LENSES

AETNA TELECOMMUNICATIONS
LABORATORIES



COMPACT BI-DIRECTIONAL COUPLER USING LENSES

AETNA TELECOMMUNICATIONS
LABORATORIES



FIBER BEAMSPLITTER COUPLER

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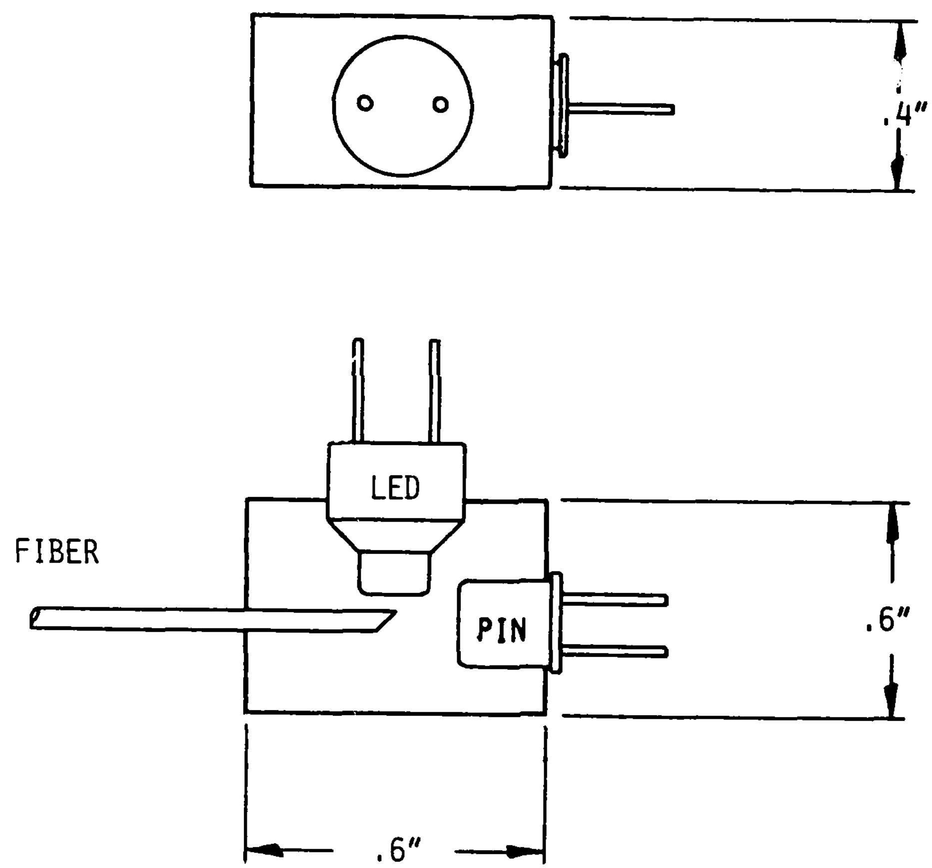
LABORATORIES

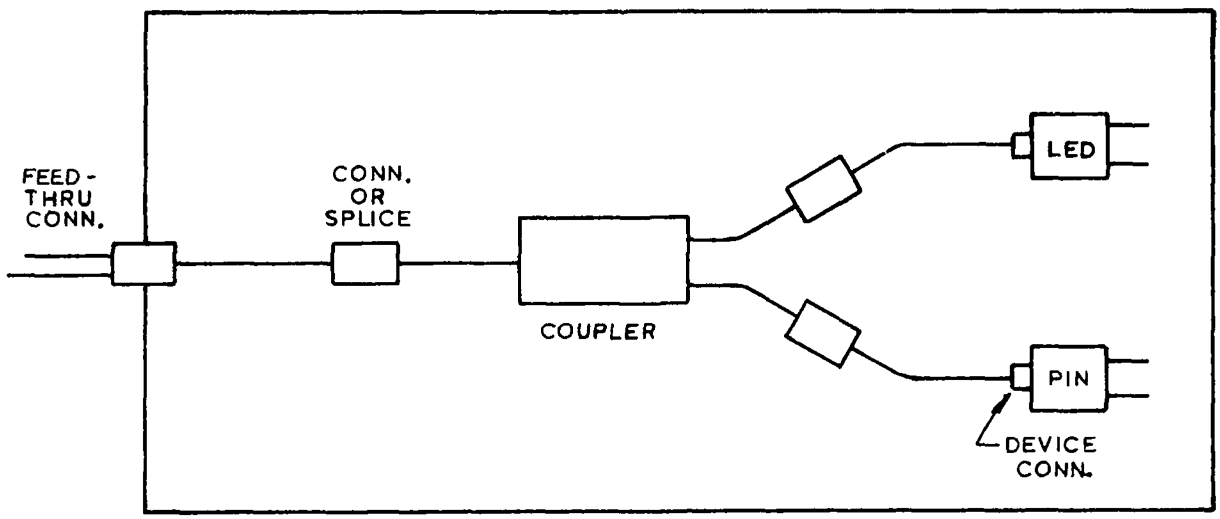
<u>ACTIVE COUPLERS</u>

- INCORPORATE SOURCE AND/OR DETECTOR IN COUPLER BODY
- DESIGN CAN ELIMINATE NEED FOR MULTIPLE CONNECTORS OR SPLICES ⇒ LOWER COST, LOWER LOSS
- INEXPENSIVE MOLDED PLASTIC BODY LOWERS COST OF COUPLER AND LABOR
- USING SOURCE AND DETECTOR FOR COUPLING YIELDS LOWER NET LOSSES, HIGHER COUPLED POWER
- CAN ALSO BE DESIGNED AS A WDM COUPLER

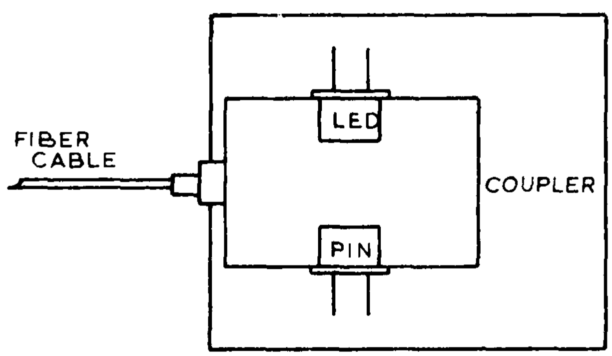


ACTIVE BIDIRECTIONAL COUPLER

TRANSCEIVER WITH F.B.T. COUPLER



TRANSCEIVER WITH ACTIVE COUPLER



ADVANTAGES OF ACTIVE COUPLER DESIGN

- ELIMINATES SPLICES, CONNECTORS
- SAVES INSTALLATION TIME, COST, MANPOWER
- LOWER COST
- HIGHER COUPLED POWER
- RUGGED DESIGN
- SMALL VOLUME
- USEFUL FOR λ MUX

FIBER OPTIC SENSORS

- COMPATIBLE WITH FIBER OPTIC TRANSMISSION SYSTEM
- MULTIMODE SENSORS ARE BEING DEVELOPED FOR MANY APPLICATIONS

  TEMPERATURE,
  PRESSURE,
  ACOUSTIC,
  MOTION,
  AND MANY OTHERS
- COMPACT PASSIVE SENSORS ARE SUITABLE FOR IN-BUILDING USE WITH LANS; FOR EXAMPLE, TEMPERATURE PROBES FOR ENERGY MANAGEMENT

FIBER OPTIC SENSING SYSTEMS

UNIQUE ADVANTAGES OF FIBER OPTICS FOR SENSING:

- ALL THE USUAL ADVANTAGES OF FIBER OPTIC TRANSMISSION
  - LIGHT WEIGHT, SMALL SIZE
  - IMMUNITY TO EMI
  - DOES NOT RADIATE
  - NO SPARK OR SHOCK HAZARD
  - NO GROUND LOOPS
  - LARGE BANDWIDTH, LOW LOSS
- PLUS SPECIAL BENEFITS FOR SENSING
  - FIBER OPTICS IS COMPATIBLE WITH UNIQUE OPTICAL SENSORS FOR PRESSURE, TEMPERATURE, SOUND, ETC.
  - REMOTE SENSING USING FIBER OPTIC LINES
  - PASSIVE SENSING: NO ELECTRICAL POWER REQUIRED AT THE SENSOR LOCATION
  - PASSIVE MULTIPLEXING SYSTEMS EXIST FOR COMBINING LARGE NUMBERS OF SENSORS ON ONE LINE

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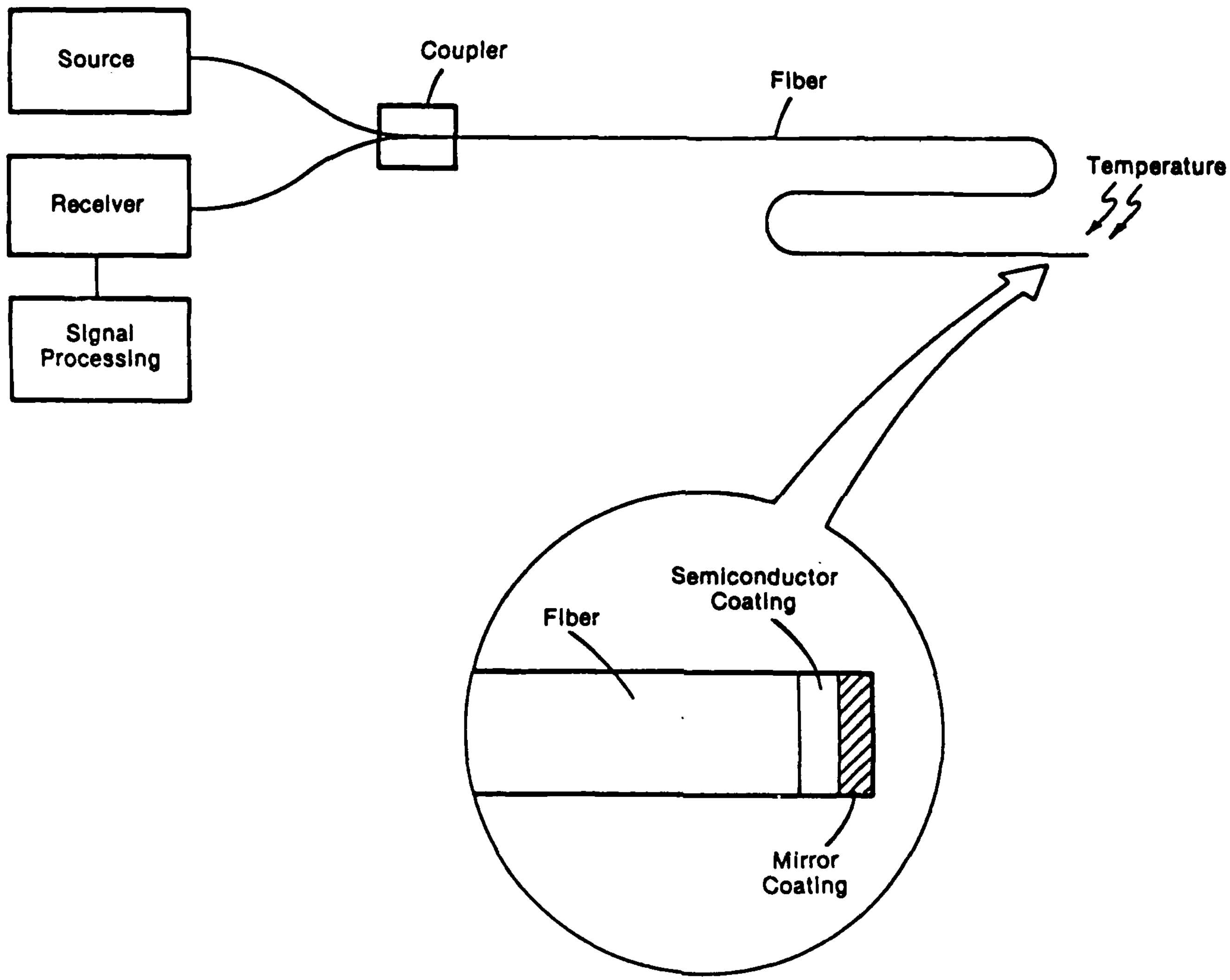
COMPACT FIBER TEMPERATURE SENSOR



Enlarged View of End of Fiber

AETNA TELECOMMUNICATIONS LABORATORIES

RICHARD SOREF received the Ph.D. degree in Electrical Engineering from Stanford University in 1964. He is currently a Member of the Technical Staff at Sperry Research Center in Sudbury, Massachusetts where he has conducted numerous research programs in electro-optics over the past 17 years. His current interests include fiber-optic sensors and optical switching.

SPERRY
RESEARCH CENTER

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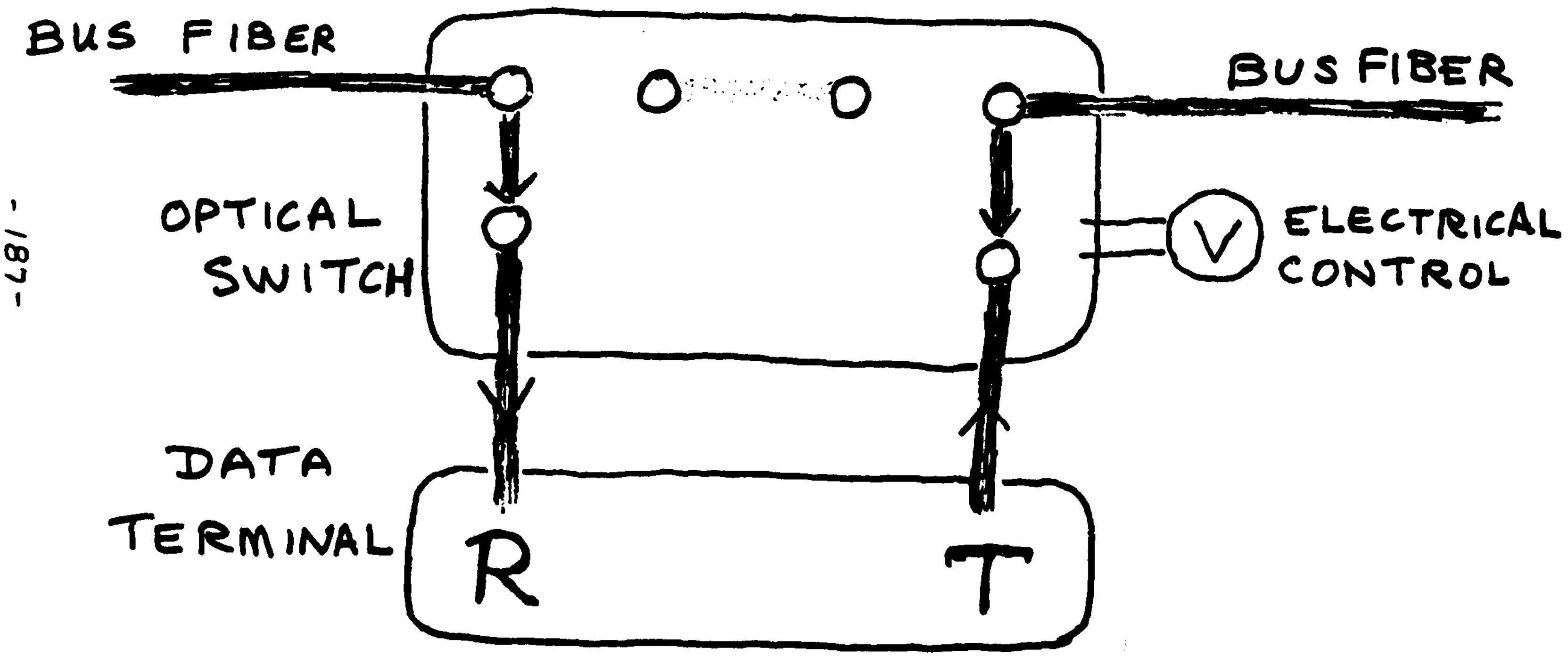
TELEPHONE (617) 369-4000

MULTIMODE FIBER-OPTICAL SWITCHES

Richard A. Soref
Sperry Research Center
Sudbury, Massachusetts 01776

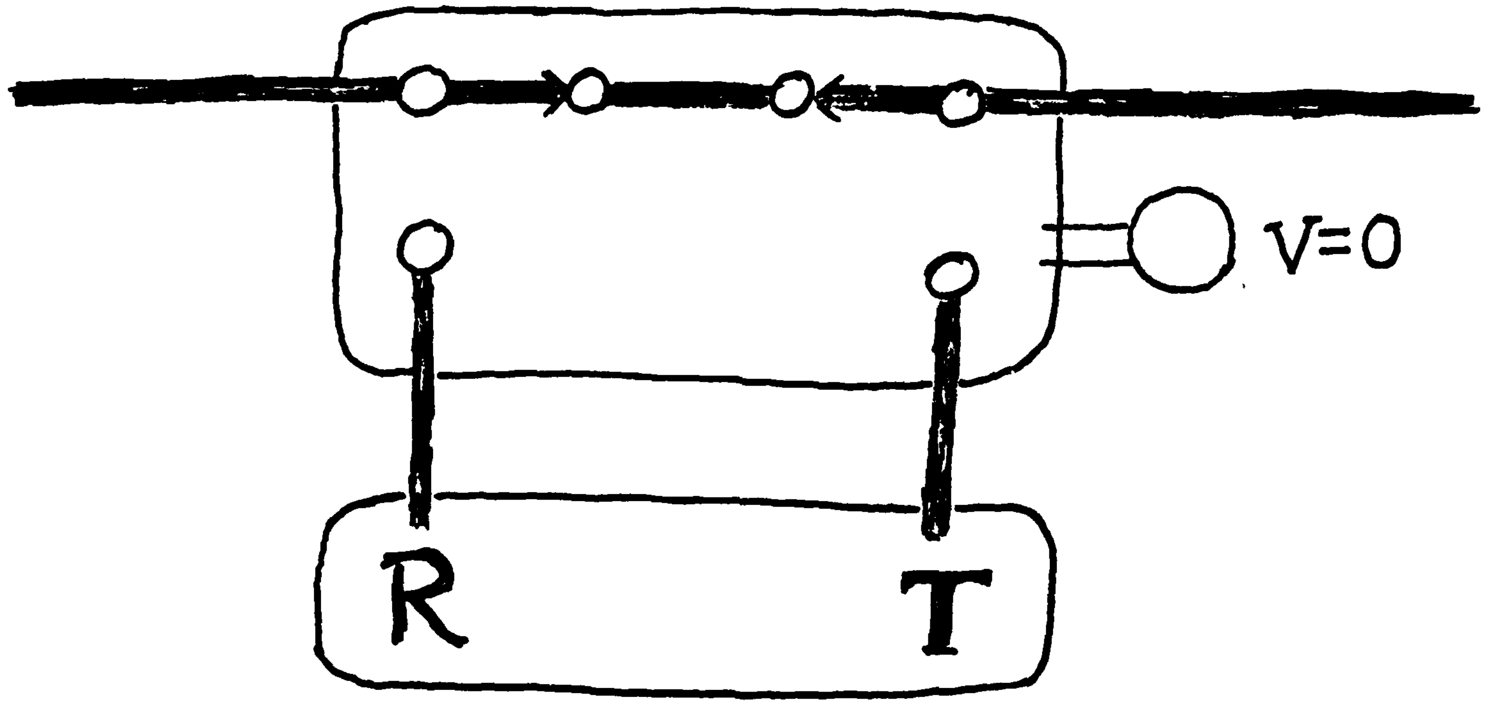
Low-loss fiber optical switches, especially 2 x 2 bypass switches, are useful components in local area networks. This paper will survey several techniques for making such components, including the electro-mechanical, magneto-optical, and electro-optical liquid crystal techniques.

TRANSMIT/RECEIVE MODE



R.A.S./Sperry-1

BYPASS MODE



ELECTRO-MECHANICAL

- NIPPON ELECTRIC
- SIEMENS
- KAPTRON
- AMERICAN TIME
- BATTELLE-GENEVA

R.A.S./Sperry - 3

ELECTRO-OPTICAL

- SPERRY (LIQUID CRYSTAL)
- SPERRY (POCKEL'S EFFECT)
- BELL LABS (LIQUID CRYSTAL)
- HEWLETT PACKARD (LIQUID CRYSTAL)

R.A.S. / Sperry - 4

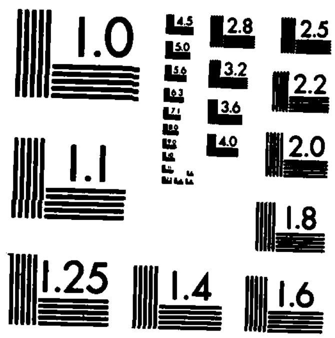
MAGNETO-OPTICAL

- FUJITSU (FARADAY ROTATION)
- SPERRY (STRIPE DOMAIN)

R.A.S./Sperry-5

AD-A126 110 PROCEEDINGS OF CONFERENCE ON LOCAL AREA MILITARY NETWORKS GRIFFISS AFB NEW YORK 28-30 SEPTEMBER 1982(U) ROME AIR DEVELOPMENT CENTER GRIFFISS AFB NY 3/6

UNCLASSIFIED D B WARMUTH ET AL. 1982 F/G 17/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ELECTRO-WETTING

- BELL LABS

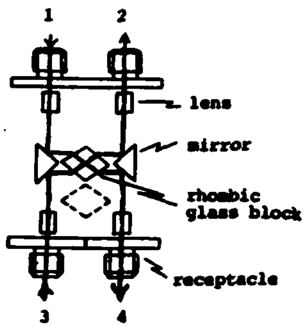
ACOUSTO-OPTICAL

PIEZO-ELECTRIC, ETC.

R.A.S. /Sperry — 6

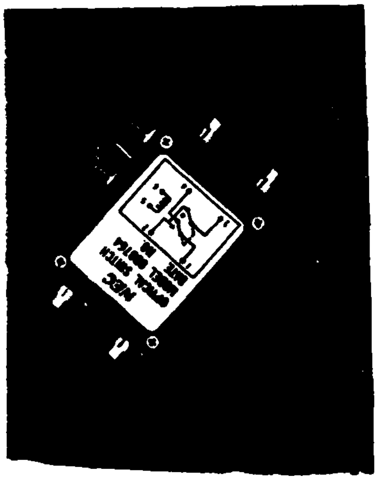
NIPPON
ELECTRIC
COMPANY

movable
rhomb



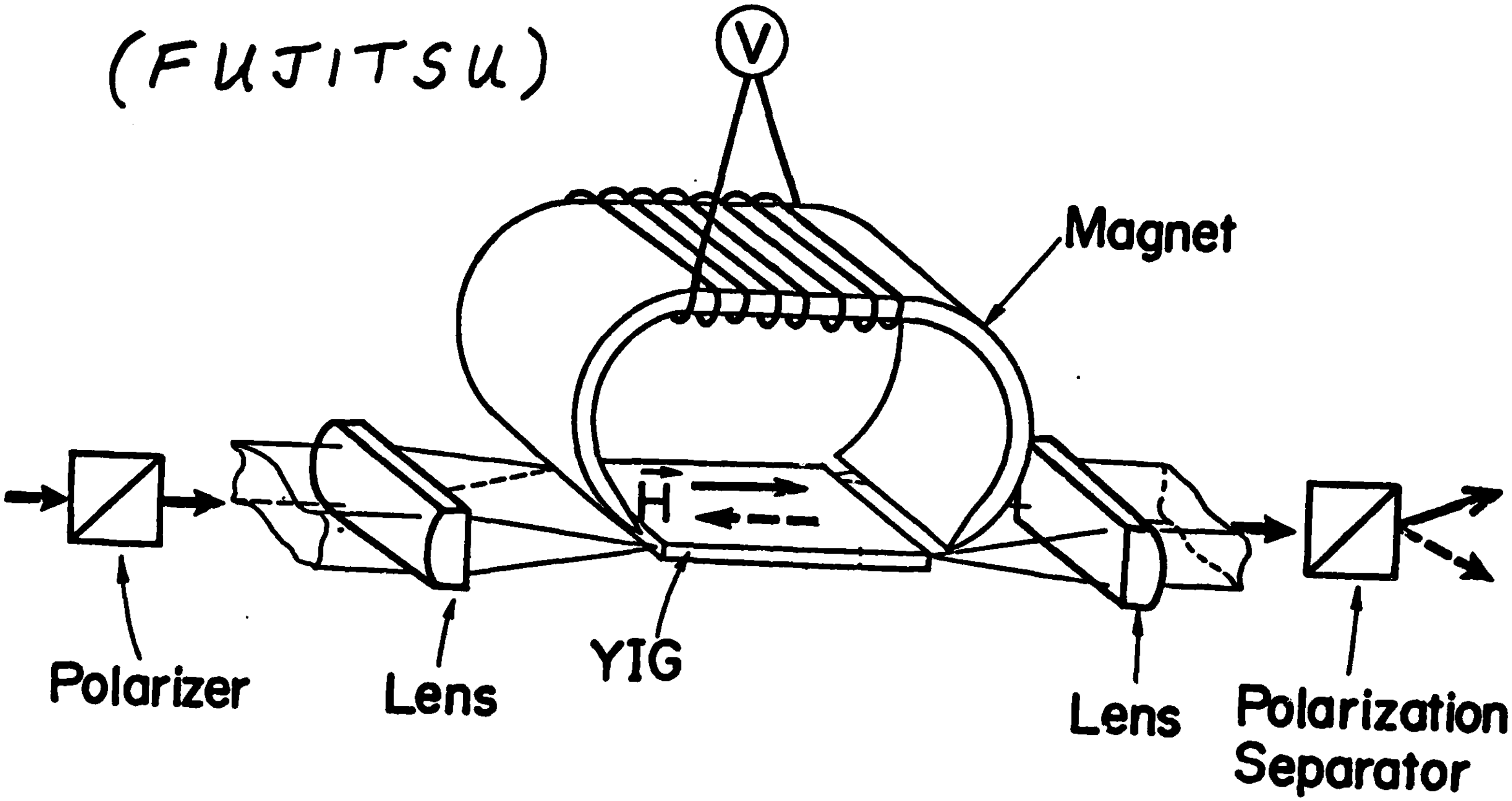
R.A.S./Sperry-7

R.A.S./Sperry-B

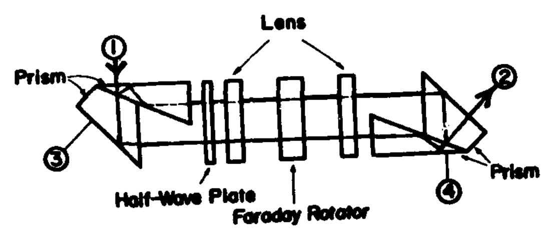


Magneto-optical switch (bi-stable)

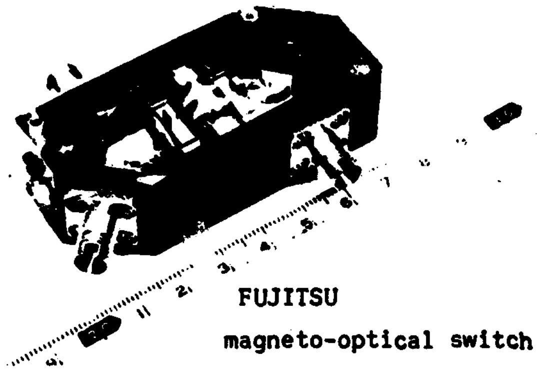
(FUJITSU)



R.A.S./Sperry-9.



R.A.S./Sperry – 10



FUJITSU
magneto-optical switch

R.A.S/Sperry–11

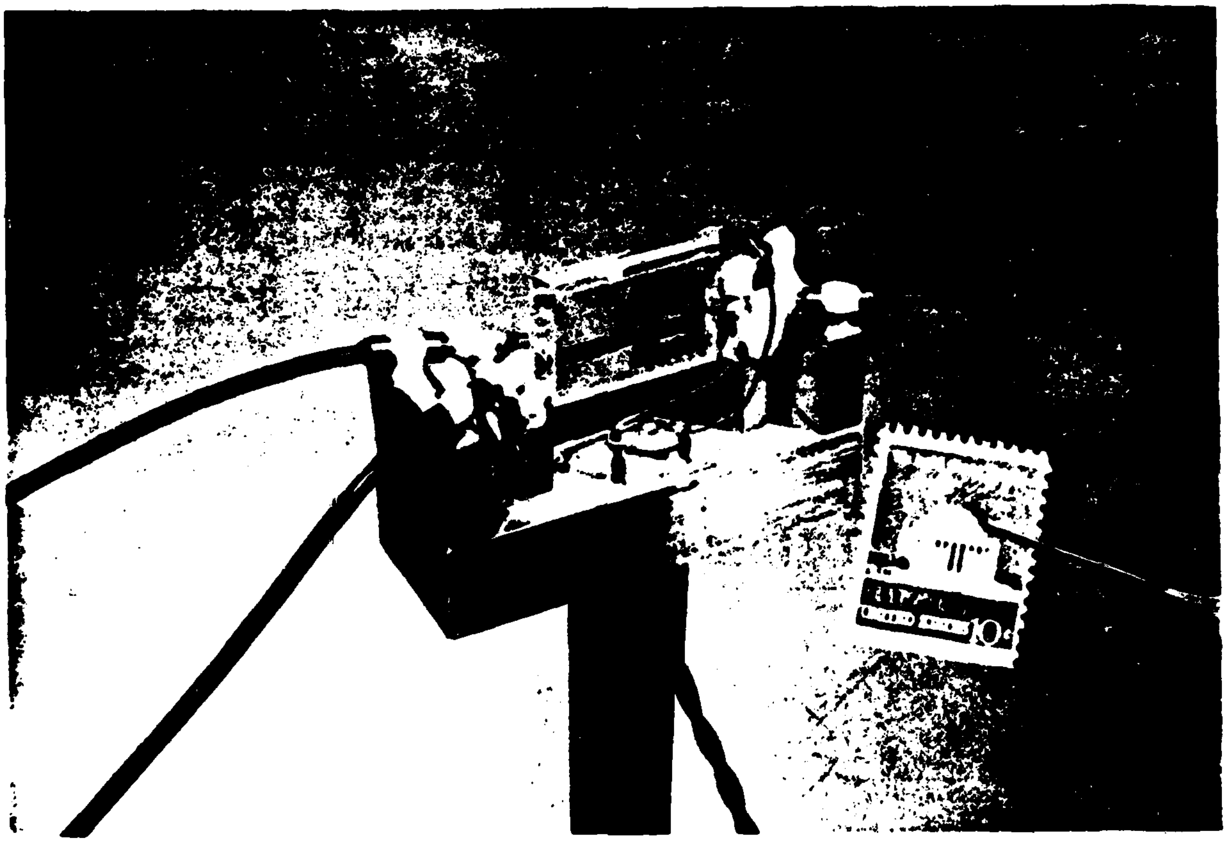


FIG. 2. Working model of 2 x 2 double-pass liquid-crystal fiber-optical switch.

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R.A.S./Sperry – 13

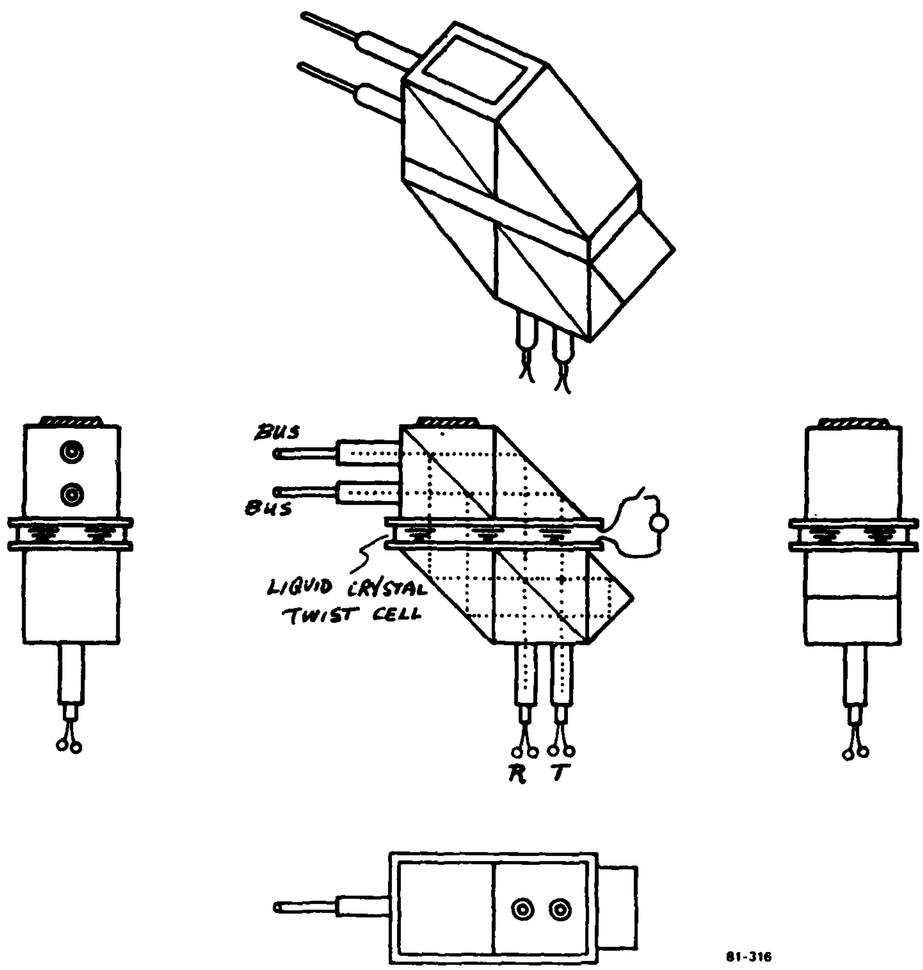

FIG. 8 Fiber optical bypass switch: in-plane approach based on Figs. 2 and 4.

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R.A.S./Sperry – 14

INS. LOSS: 1 to 2 dB

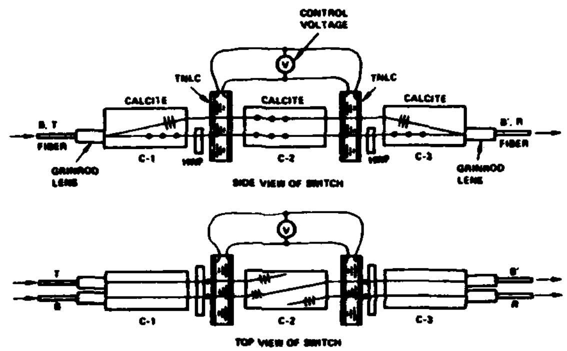
OPER. VOLTAGE: 3V

CROSSTALK: -30 dB (ON STATE)

CROSSTALK: -17 dB (OFF STATE)

SW. SPEED: 100 ms

R.A.S./Sperry - 15



R.A.S./Sperry-16

INS. LOSS: 1 to 2 dB

OPER. VOLTAGE: 5 V

CROSSTALK: −33 dB (ON STATE)

CROSSTALK: −35 dB (OFF STATE)

SW. SPEED: 100 ms

R.A.S./Sperry – 17

Local Network Issues (1030-1230 29 Sep)

Session Chairman: Mr. Dick Metzger - RADC/COTD

"Layered Protocol Structures - the OSI Model," Dr. John Day, Micro Data Corp.

This presentation will discuss the use and applicability of layered protocol structures with emphasis on the current open system inter-connect (OSI) reference model currently being developed by the International Standards Organization. Its potential applicability to local area networks will be discussed.

"Internetting Local Area Networks," Dr. David Clark, Massachusetts Institute of Technology

This presentation will discuss the technical issues involved in interconnecting multiple local area networks. In addition, the MIT experience using TCP/IP as the internet protocol will be discussed.

"Security Issues and Key Distribution in Local Area Networks," Dr. Deepinder Sidhu, Burroughs Corporation

This presentation will discuss two sub topics. The first will present research that has been accomplished in developing key distribution protocols for secure network links. The second topic will address security issues related to the design of local area networks.

"Design Trade-Offs for Survivable Local Packet Networks," Mr. James A. Keddie, Magnavox Data Systems Inc.

An approach to achieving a survivable network is to incorporate many of the currently used survivability design techniques directly into a top down systems approach. This presentation deals with some of the survivability issues which should be considered when designing, implementing, and operating a local area network for use within a command and control system.

LAYERED PROTOCOL ARCHITECTURE:

THE ISO REFERENCE MODEL OF OPEN SYSTEMS INTERCONNECTION

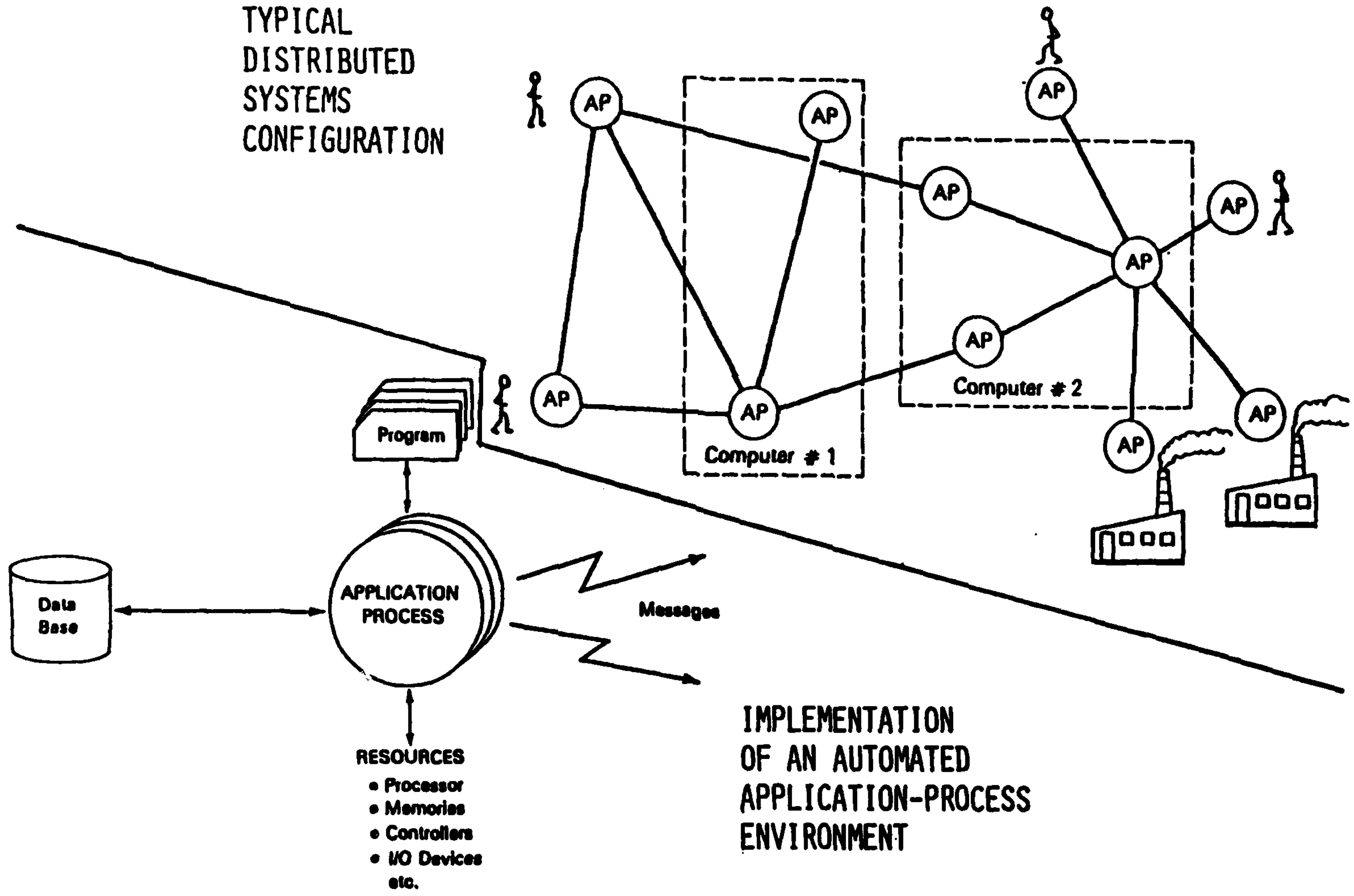
JOHN NEUMANN Microdata Chairman, ANSI OSI Transport	and	RICHARD desJARDINS Computer Technology Associates Chairman, ISO OSI

Presented to Local Area Military Networks Conference

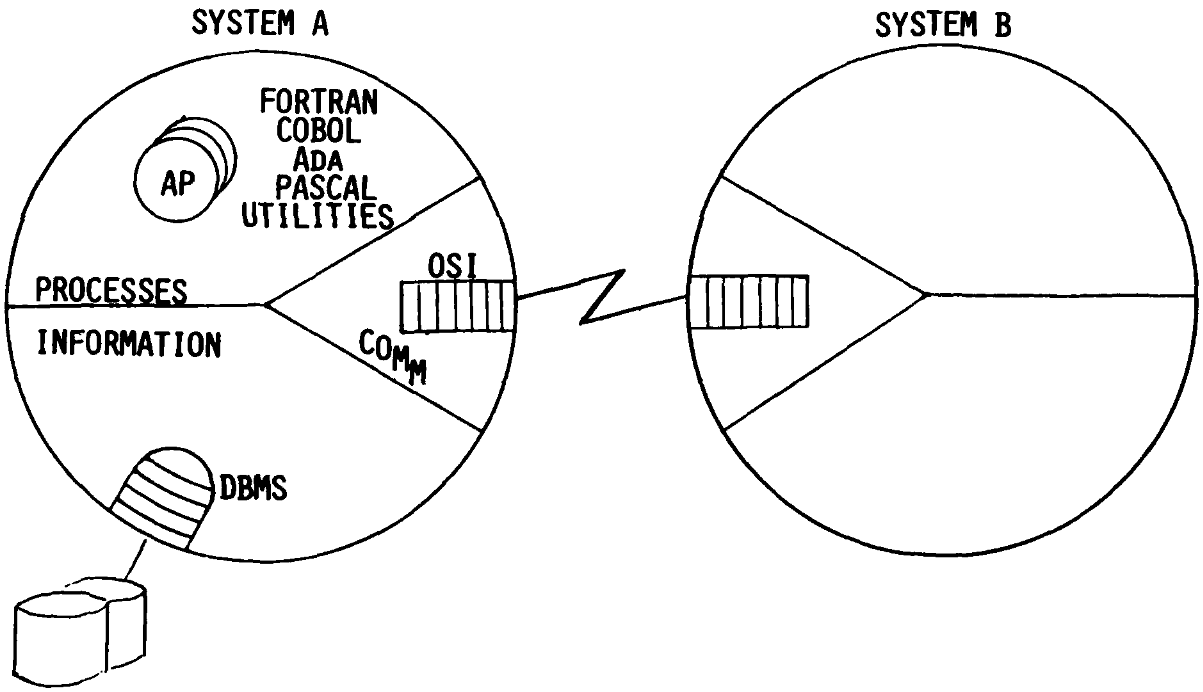
Rome Air Development Center

28-30 September 1982

FUNCTIONAL ALLOCATION OF APPLICATION-PROCESSES IN DISTRIBUTED SYSTEMS: TERMINALS, COMPUTERS, PLANTS (SENSORS/EFFECTORS)



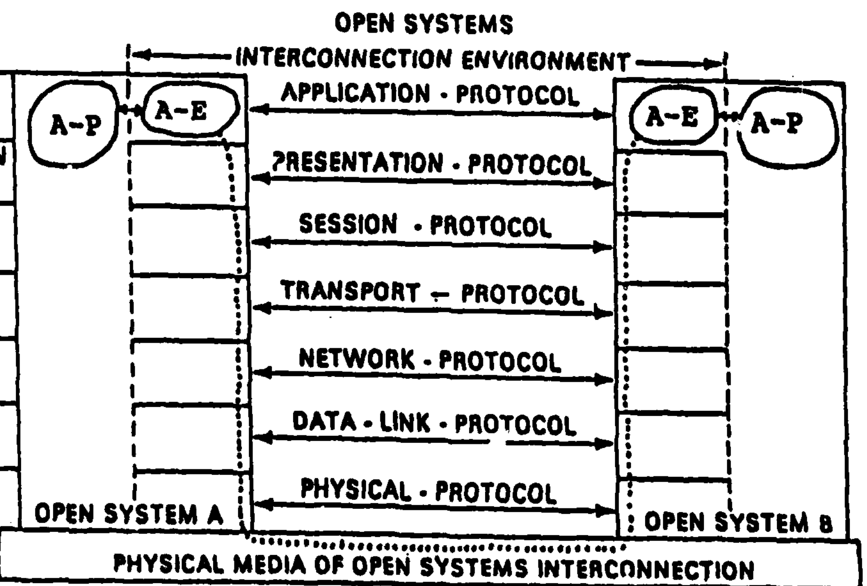
SYSTEMS COMMUNICATE USING OSI PROTOCOLS



REFERENCE MODEL OF OPEN SYSTEMS INTERCONNECTION (OSI) PROTOCOL STANDARDIZATION

- DEFINITION OF OSI: INTERCONNECTION OF SYSTEMS "OPEN" TO USE OSI STANDARD PROTOCOLS
- "REFERENCE MODEL": COMMON ARCHITECTURAL BASIS FOR COORDINATING OSI STANDARDS
- SECURE COMMUNICATIONS: BUILT USING OSI PROTOCOLS + SECURITY FEATURES
- ADVANTAGES OF USING OSI AS A DESIGN REFERENCE:
  --LAYERED ARCHITECTURE PROVIDES ENGINEERING STABILITY, ECONOMIC ADVANTAGES
  --WIDESPREAD ADOPTION OF OSI MODEL (ISO/ANSI/NBS) ASSURES COMMERCIAL AVAILABILITY
  --INTEROPERABILITY GREATLY ENHANCED
- DARPA/DOD/NCS/NBS STANDARD PROTOCOLS: COMPATIBLE WITH OSI MODEL

PURPOSE OF LAYER	
INFORMATION EXCHANGE	APPLICATION LAYER
SYNTAX TRANSFORMATION, SOURCE ENCRYPTION	PRESENTATION LAYER
SOURCE ADDRESSING, DIALOG STRUCTURING	SESSION LAYER
END-TO-END TRANSFER ASSURANCE, SYSTEM ENCRYPTION	TRANSPORT LAYER
SYSTEM ADDRESSING, ROUTING	NETWORK LAYER
SINGLE-LINK DATA TRANSFER LINK ENCRYPTION	DATA LINK LAYER
PHYSICAL CIRCUIT ACTIVATION BIT TRANSFER	PHYSICAL LAYER

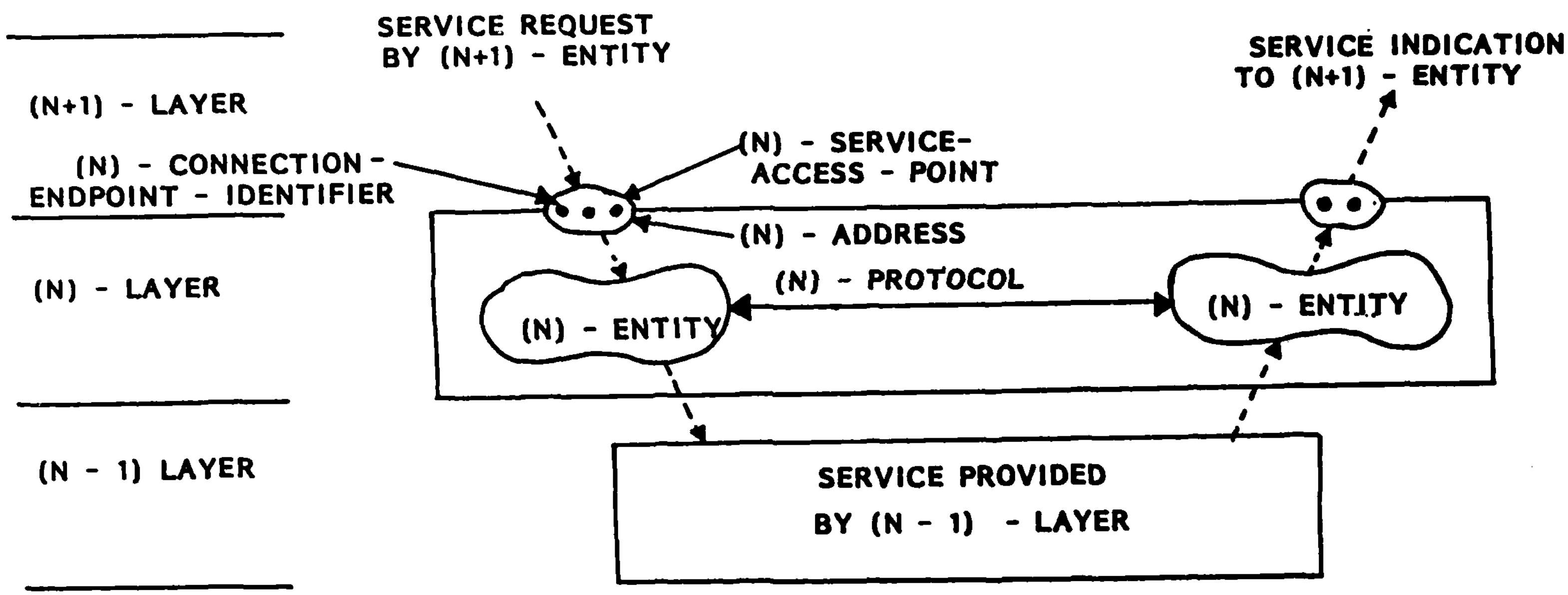


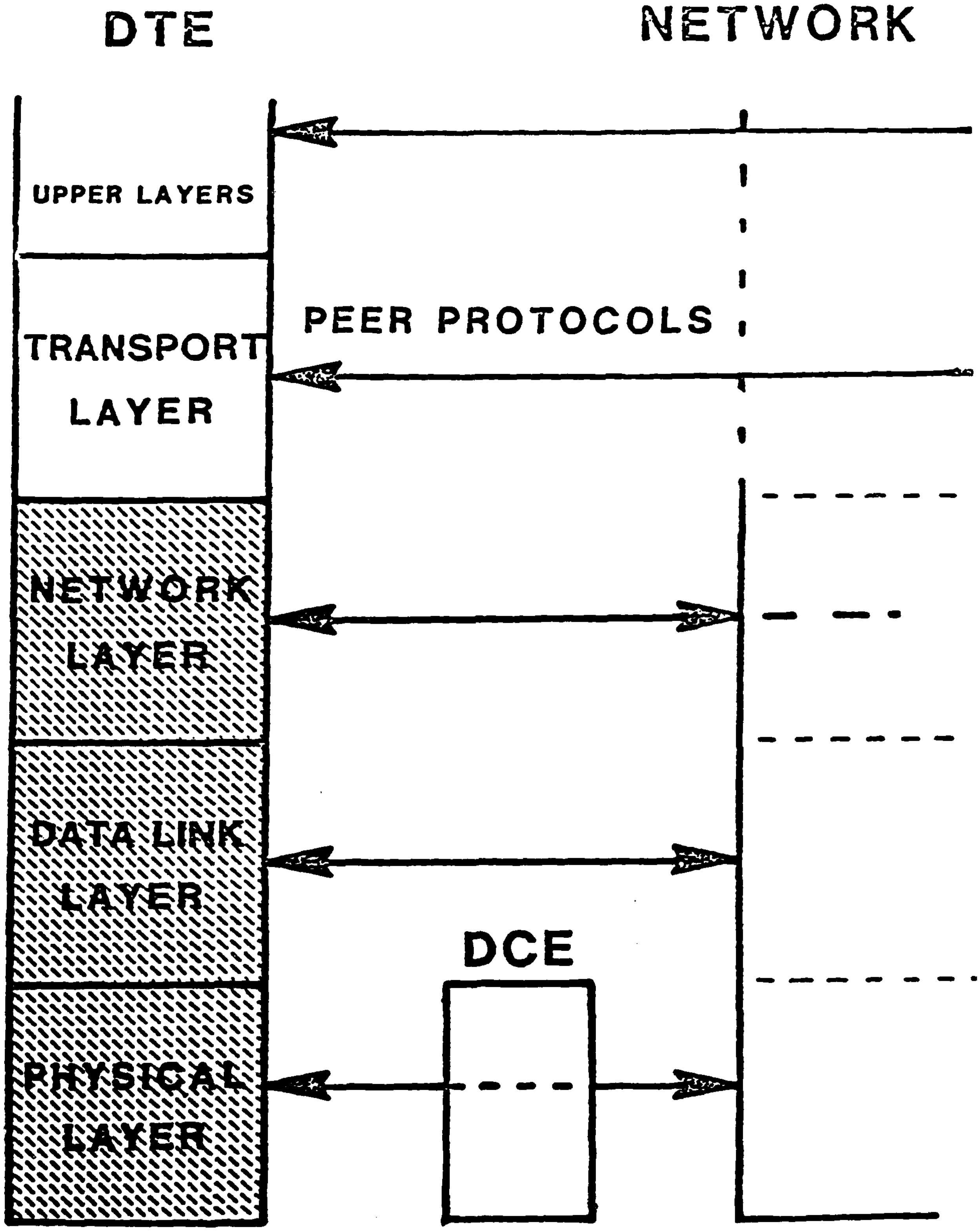
A-P = application-process, A-E = application-entity

ROLES OF STANDARDS BODIES

- INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO):
  - --TECHNICAL COMMITTEE 97- INFORMATION PROCESSING SYSTEMS
  - --SUBCOMMITTEE 16 - OPEN SYSTEMS INTERCONNECTION
  - --SUBCOMMITTEE 6 - DATA COMMUNICATIONS
- AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI):
  - --TECHNICAL COMMITTEE X3 - INFORMATION PROCESSING SYSTEMS
  - --TECHNICAL COMMITTEE X3T5 - OPEN SYSTEMS INTERCONNECTION
  - --TECHNICAL COMMITTEE X3S3 - DATA COMMUNICATIONS
- INTERNATIONAL TELEPHONE AND TELEGRAPH CONSULTATIVE COMMITTEE (CCITT)

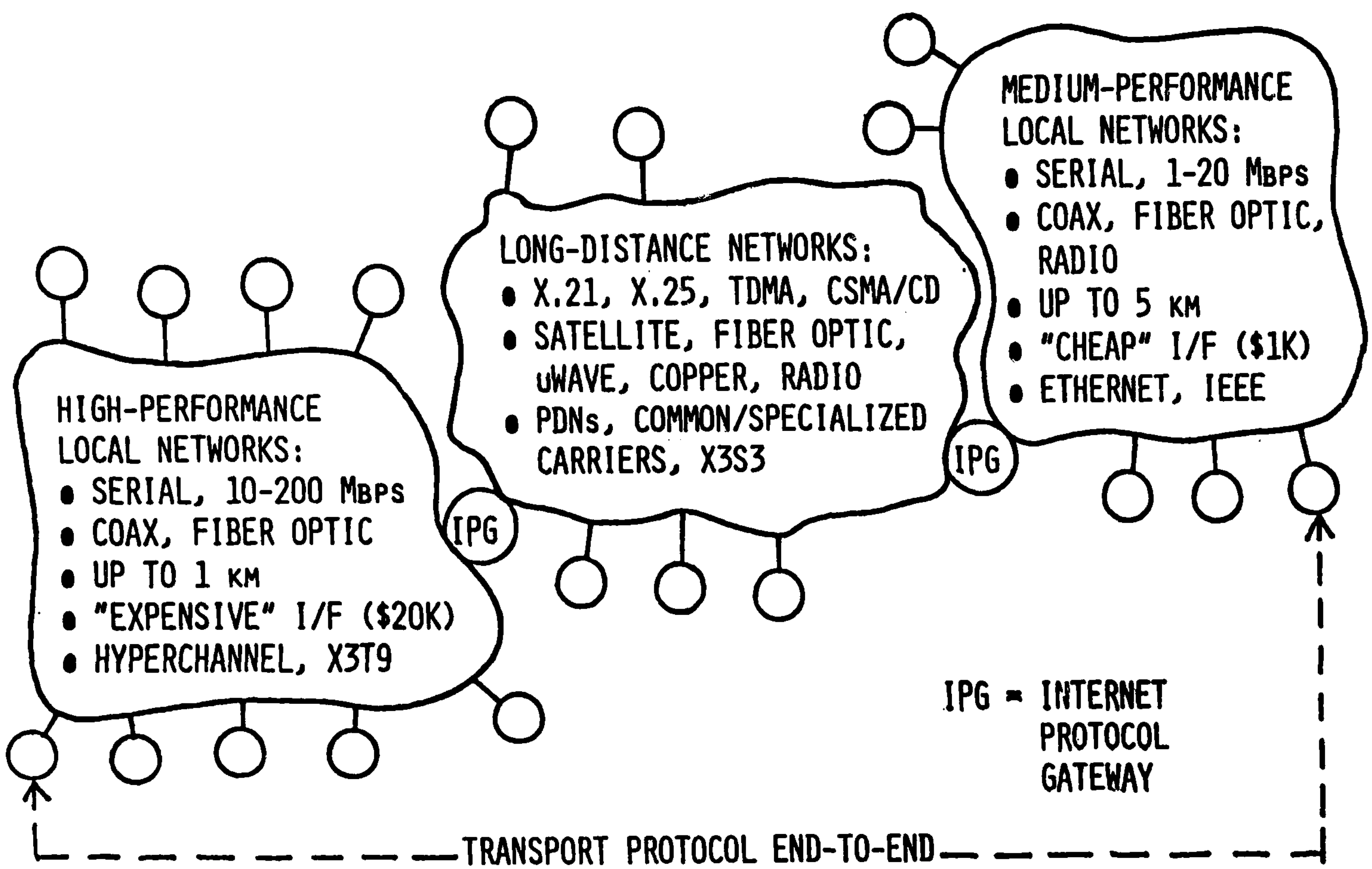
SERVICE AND PROTOCOL ARCHITECTURE OF EACH LAYER





DTE
NETWORK
UPPER LAYERS
TRANSPORT LAYER
PEER PROTOCOLS
NETWORK LAYER
DATA LINK LAYER
DCE
PHYSICAL LAYER

SERIAL NETWORKING TECHNOLOGIES



MIDDLE AND UPPER LAYERS

<u>TRANSPORT LAYER</u>: PROVIDE COST-EFFECTIVE, RELIABLE END-TO-END DATA TRANSFER

- CLASS 0 -- SIMPLE CLASS
- CLASS 1 -- BASIC ERROR RECOVERY CLASS
- CLASS 2 -- MULTIPLEXING CLASS
- CLASS 3 -- ERROR RECOVERY CLASS
- CLASS 4 -- ERROR DETECTION AND RECOVERY CLASS

WORLD TRANSPORT DRAFT SERVICE/PROTOCOL STANDARD ADOPTED IN JUNE 1982

<u>SESSION LAYER</u>: ESTABLISH AND CONTROL DIALOG

WORLD SESSION DRAFT SERVICE/PROTOCOL STANDARD NOT LIKELY UNTIL 1983

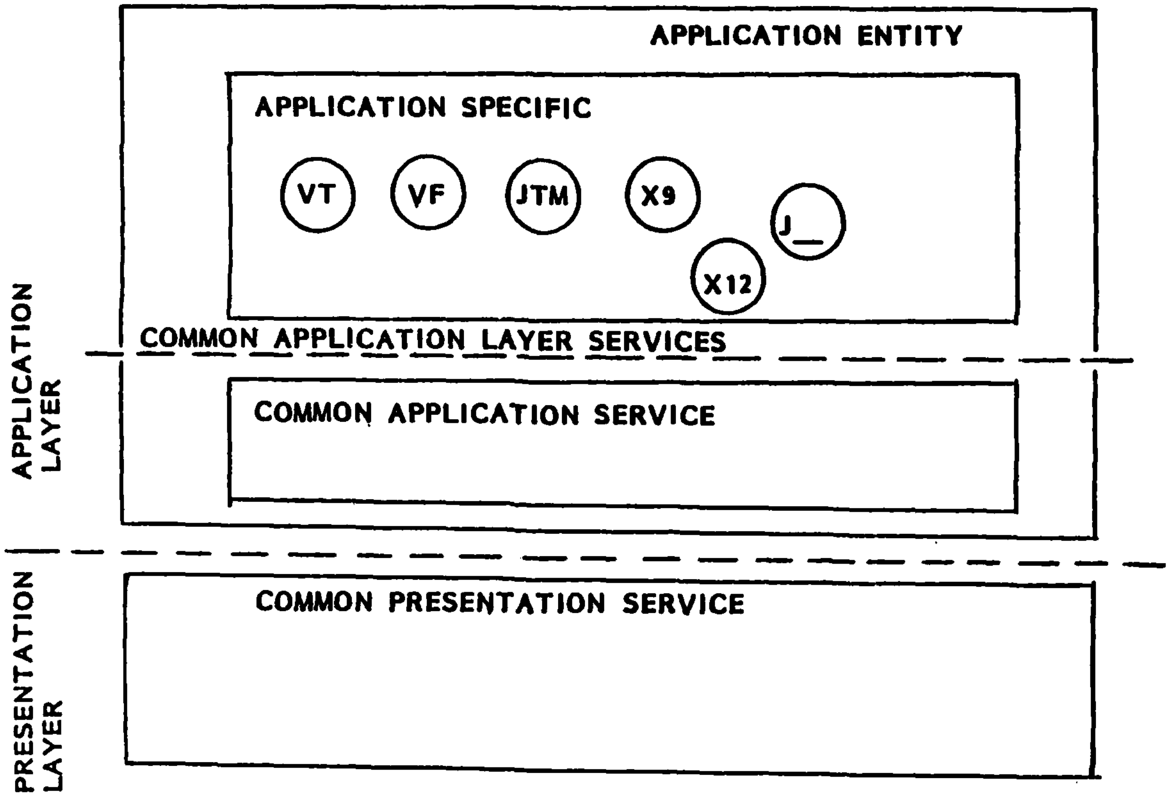
SESSION AND TRANSPORT STANDARDS LIKELY TO BE COMPATIBLE: ISO/CCITT/ANSI/ECMA/NBS

<u>PRESENTATION LAYER</u>: PROVIDE TRANSFORMATIONS OF SYNTAX

<u>APPLICATION LAYER</u>: PROVIDE STANDARD APPLICATION-PROCESS INTERCONNECTIONS

PRESENTATION AND APPLICATION LAYER ARCHITECTURE AND SERVICE DESCRIPTIONS MAY BE AGREED BY 1983, DRAFT STANDARDS FOR VIRTUAL TERMINAL/VIRTUAL FILE/JOB TRANSFER NOT LIKELY BEFORE 1984

UPPER LAYER ARCHITECTURE

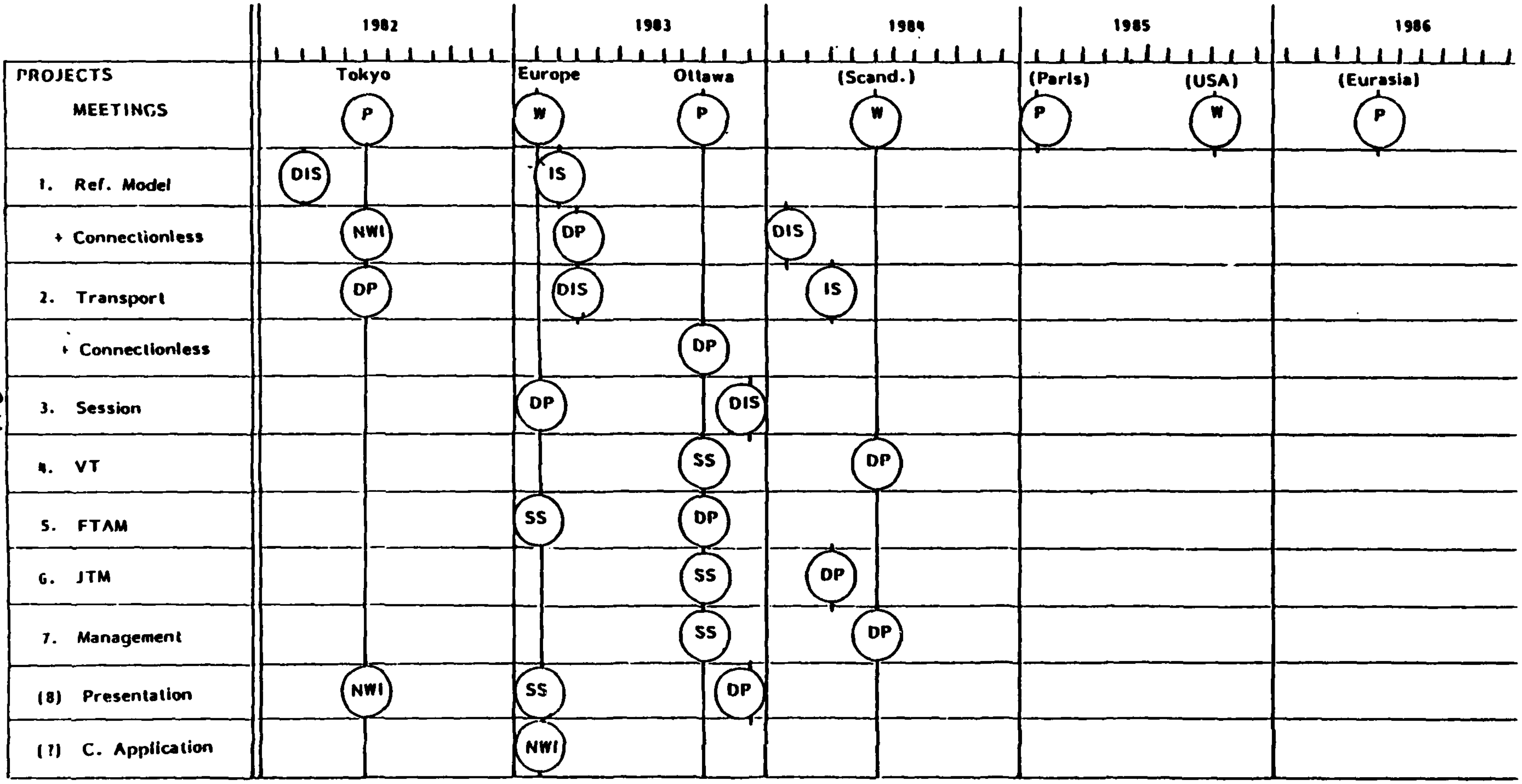


OPEN SYSTEMS INTERCONNECTION

TIME TABLE AS OF 8/82

- BASIC REFERENCE MODEL OF OSI IS CURRENTLY BEING PROCESSED AS WORLD STANDARD (ISO DRAFT INTERNATIONAL STANDARD 7498)
- LOWER LAYERS 1-3 ARE FAIRLY MATURE IN PUBLIC NETWORK APPLICATIONS (i.e., HDLC, X.25/X.75)
- LOCAL AREA NETWORKS (i.e., IEEE 802, SC13 LDDI) ARE RECEIVING GREAT ATTENTION, SHOULD HAVE DRAFT STANDARDS IN LATE 1982
- INTERNET STANDARDS FOR LANs, PUBLIC-TO-PRIVATE INTERFACE, ARE VERY ACTIVE IN X3S3 AND SC6, SHOULD GET DRAFTS IN 1983
- WORLD TRANSPORT STANDARD IS NOW ISO DRAFT PROPOSED STANDARD (ISO DP 8072/8073)
- WORLD SESSION STANDARD IS DUE AS DRAFT PROPOSED STANDARD IN 1983
- DRAFT MESSAGE STANDARDS (i.e., CCITT MESSAGE HANDLING SYSTEMS, NBS FIPS MESSAGE FORMAT STANDARD) WILL BE AVAILABLE IN 1982
- NORTH AMERICAN VIDEOTEX SPECIFICATION, CCITT TELETEX DRAFT, WILL BE AVAILABLE IN 1982
- COMMON PRESENTATION AND APPLICATION PROTOCOLS (including FILE TRANSFER, VIRTUAL TERMINAL, JOB TRANSFER, SYSTEMS MANAGEMENT) WILL HAVE STABLE SERVICE DEFINITIONS IN 1983, DRAFT PROPOSED STANDARDS IN 1984

SC16 4-YEAR PLAN



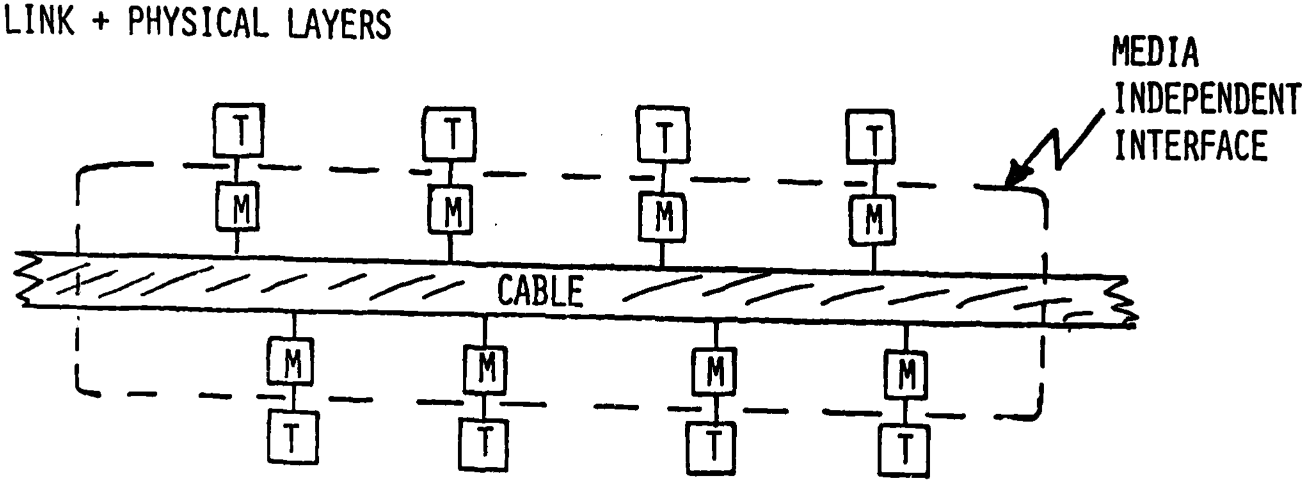
LEGEND: P = WG/Plenary meetings, W = WG meetings only.
NWI = Either NWI is prepared or need for NWI is denied.
SS = Stable Service Definition.

NOTE: DP → DIS = 10 months,
DIS → IS = 12 months.
(best cases)

Rdj 11 June 1982

LOCAL AREA NETWORK STANDARDS

DATA LINK + PHYSICAL LAYERS



M = MEDIA ACCESS UNIT, T = DATA TERMINAL EQUIPMENT

PHYSICAL LAYER:

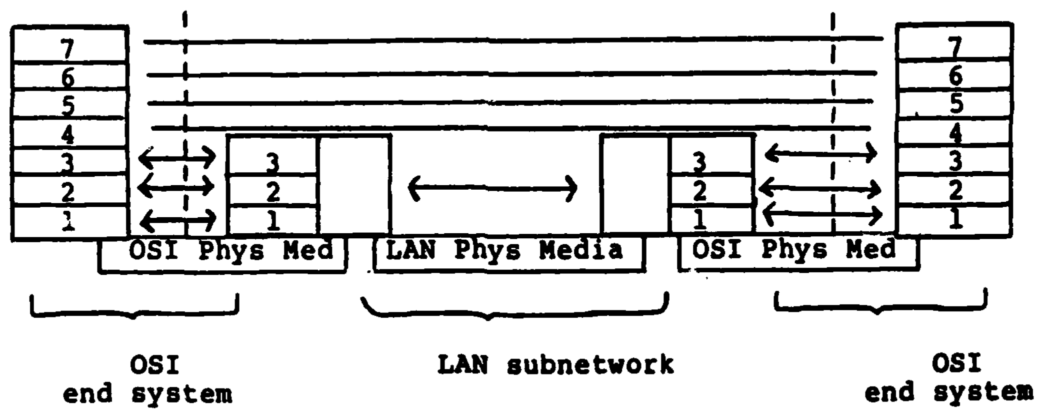
- SEVERAL TYPES OF MEDIA POSSIBLE: COAX, OPTICAL, RADIO
- BASEBAND OR BROADBAND POSSIBLE

DATA LINK LAYER:

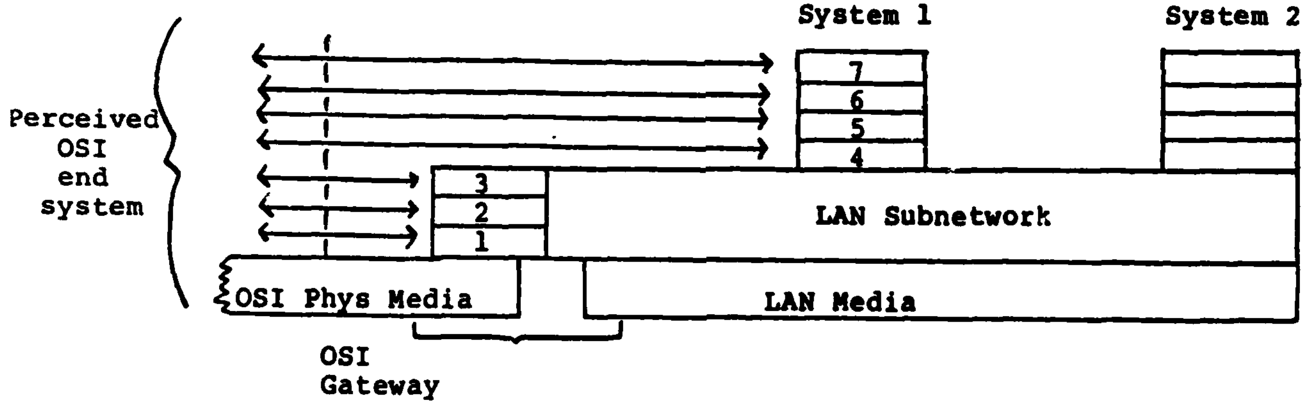
- TWO TYPES OF MEDIA ACCESS: CSMA/CD, TOKEN PASSING
- FRAME STRUCTURE, ADDRESSING, ERROR/FLOW CONTROL

STANDARDS: IEEE 802, ETHERNET (PROPRIETARY), ANSI X3T9.5 (50 MBPS)

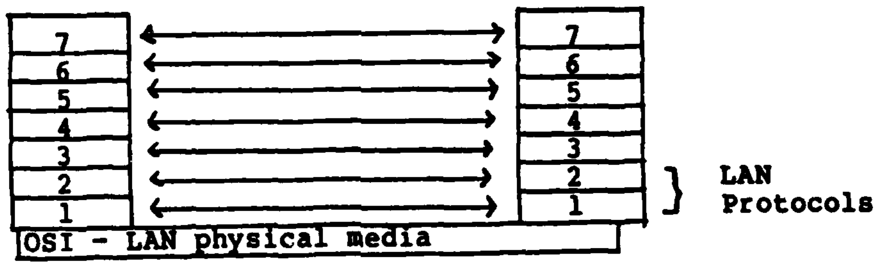
USE OF LAN AS INTERCONNECTING SUBNETWORK



USE OF LAN TO CONSTRUCT COMPOSITE END-SYSTEMS



DIRECT USE OF LAN SYSTEMS AS OSI END-SYSTEMS



ENHANCEMENTS OF REFERENCE MODEL FOR LANs

SEVERAL PROPOSALS TO ENHANCE REFERENCE MODEL TO BETTER MEET REQUIREMENTS FOR LAN DEVELOPMENTS:

- BROADCAST

  (Data Link Layer service, no acknowledgment)

- ERROR DETECTION/CORRECTION

  (Data Link Layer function, *may be unnecessary for* LANs)

- NETWORK LAYER MINIMAL FUNCTIONALITY

  (What is minimum set of functions for systems within an LAN?)

- GATEWAYS

  (What interface functions required for LANs of various types, LANs to non-LAN networks?)

- CONTENTION RESOLUTION

  (Should this service be assigned solely to Physical Layer?)

- CHANNEL DERIVATION AND MODULATION

  (These functions should be assigned to Physical Layer)

Interconnection of Local Area Nets

David D. Clark
Laboratory for Computer Science
Massachusetts Institute of Technology

Abstract of talk

A local network is often installed as an isolated facility, but there are a number of reasons why it is desirable to connect several such networks together to form a larger facility. For example, the installation may grow too large physically to be spanned by one single link. This talk addresses the various problems that can arise when a gateway computer is used to join several local networks, with particular attention to the issues of protocol design. Local networks are very simple devices, and very simple protocols can be made to work on them. The concern is that addition of a gateway to the configuration will cause either increased complexity in the protocols or decreased performance of the network.

At the M.I.T. Lab for Computer Science there is a installation of several local networks joined together using gateways. Our experience with this facility is that good performance can be obtained, and that the problems with protocols are not serious. In fact, careful study of the protocols in use suggests that the actual problems experienced are not at all what we expected. The actual protocol implementation is not as large a task as integrating the protocol into the operating system and interfacing it to its client programs. This implies that the addition of gateways to the configuration was not an important factor in the complexity of the total task.

David D. Clark

Biographical Note
August 1982

David Clark graduated from Swarthmore College in 1966, and received his PhD from M.I.T in 1973. Since then, he has been employed at the Laboratory for Computer Science at M.I.T., where he is currently a Principal Research Scientist in the Computer Systems and Communication group.

Dr. Clark's research area is operating systems, computer networks, and the interaction of the two. He has worked on several operating systems, including the Multics system done at M.I.T. during the 1960s. He has been involved in computer networking since the early days of the ARPANet, and has designed and implemented a number of network protocols. Currently, he is Chief Protocol Architect for the DARPA Internet Protocol project.

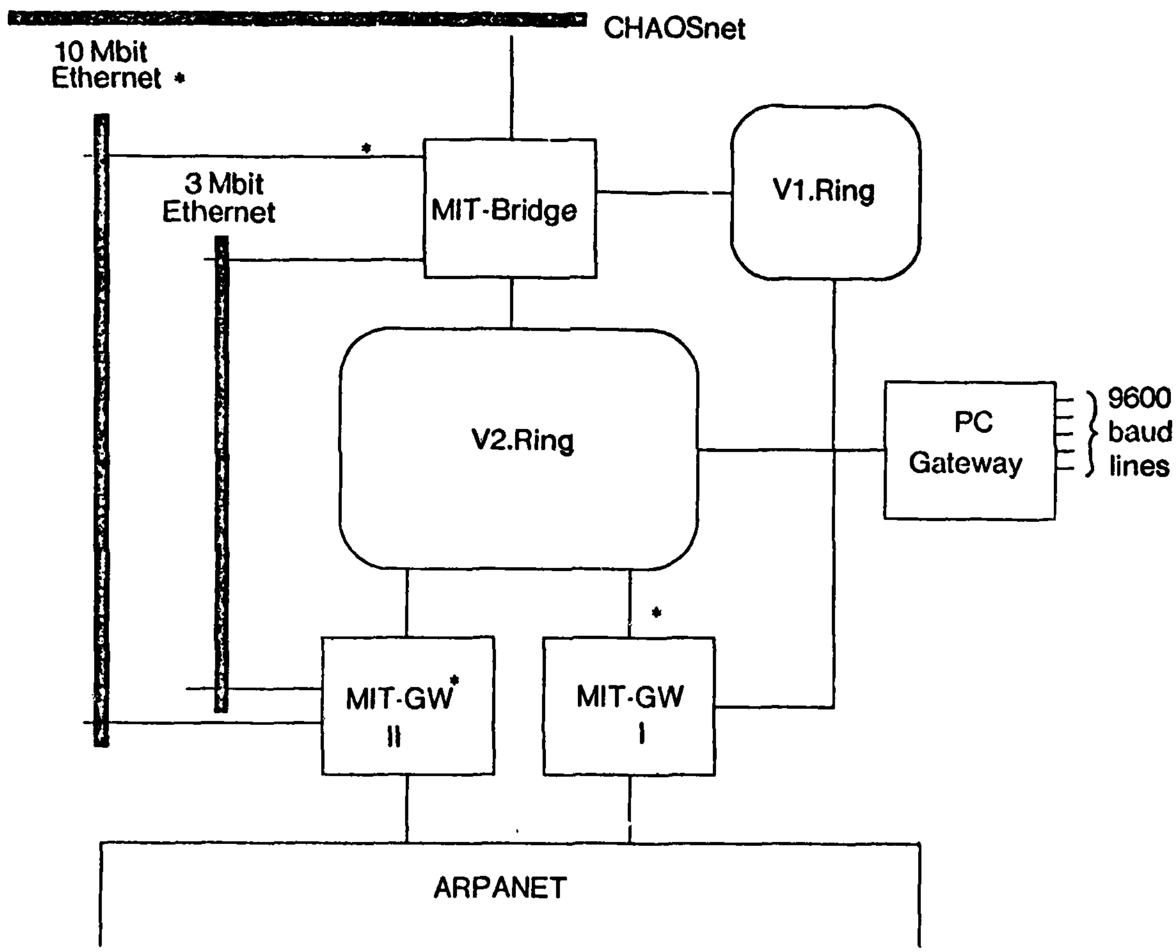
Dr. Clark has been involved for several years in a project to develop a high-speed local net at M.I.T., one based on the ring concept. This net, which is now a commercial product, is in use at M.I.T., and is part of the network configuration on which he will report in this talk.

INTERCONNECTION OF LOCAL AREA NETS
or
WHY PROTOCOLS RUN SLOWLY

David D. Clark

Laboratory for Computer Science
Massachusetts Institute of Technology

Current Network/Gateway Plan
M.I.T. Lab for Computer Science
July 1982



* not installed as of 7/1/82

Local Network Attributes

* High performance:
    High throughput
    Low delay

  It would be nice if internetting did not degrade this performance.

* Missing problems
    No routing
    No congestion

  It would be nice if internetting did not re-introduce the need to deal with these issues.

Gateway Performance

A gateway <u>can</u> be designed that has performance consistent with local networks.

Measurements of current M.I.T. gateway show 250-350 instructions per packet.

For a DEC 11/23, this is a per packet overhead of about 1 ms.

At 1 ms. per packet, a throughput of 10 mbps is achieved with a packet of 1250 bytes.

This analysis is much too simplistic.

Protocol complexity:

Gateways do raise the possibility of:
- Increased delay -> multi-packet windows
- Buffer overflow -> congestion control
- Gateway failure -> dynamic routing

But:
- Are these hard problems? (Not really.)
- Is it reasonable to ignore them under any circumstances? (Its risky.)

What <u>is</u> hard about protocols?
or
Why <u>do</u> they run so slowly?

Performance and complexity problems are usually found in:

Interfacing to the operating system.
Interfacing to the client program.

Protocols are unfamiliar, as well as difficult.

DARPA Internet Protocols

* Intended for sophisticated internetworking.
* Permits 3 levels of host address.
* Supports several transport levels.
* Much experience with correct and <u>effective</u> implementations.

The really hard problem: Using more than one protocol family.

This requires that the gateways be "multi-lingual".

DEEPINDER P. SIDHU

Deepinder P. Sidhu was born in Chachrari (Pb) India on 13 May 1944. He received his B.S. degree in Electrical Engineering from the University of Kansas, Lawrence, KN in 1966, Ph.D. in Theoretical Physics and M.S. in Computer Science from the State University Of New York at Stony Brook in 1973 and 1979 respectively.

He was Research Associate in Physics at Rutgers University from 1973 to 1975. From 1975 to 1980, he was member of the Scientific Staff at Brookhaven National Laboratory, Upton, NY and held the position of Assistant Physicist from 1975 to 1977 and Associate Physicist from 1977 to 1980. From 1980 to 1982, he was with the MITRE Corporation, Bedford, Mass. as a technical staff. Since March 1982, he has been with the the Burroughs Corporation, Paoli, PA where he is manager of the Secure and Distributed Systems department in the Research and Development Organization.

Dr. Sidhu has made several significant contributions to Theoretical Physics and has published more than 60 research papers in Physics. His notable contributions are to the development of Reggeon Field Theory for multiparticle amplitudes, development of Left-Right Symmetric Unified Gauge Theories of Electroweak Interactions, and model independent determination of the Weak Neutral Current Coupling of Quarks. The last work is considered one of the definitive pieces of work on the subject and for deciding the 1979 Nobel Prize in Physics. It was cited by S. Weinberg in his Nobel Prize acceptance speech.

Dr. Sidhu has given several invited talks at national and international conferences. Recently, his name was listed in the, "American Men and Women of Science."

Dr. Sidhu's current interests are in the area of Computer Science, particularly, computer network architectures and interconnections, protocols specification and verification, protocol standards, software development methodologies, distributed data bases, computer and network security, local area computer networks. He has written over 25 research papers in the area of protocol specification and verification, computer and network security, security verification, and design of local area computer networks. Some of these papers were presented at national and international conferences. At Burroughs, in addition to being department manager, Dr. Sidhu is a principle investigator for several IR&D projects in the area of local networks, network security, and design of high performance network front ends. Dr. Sidhu has reviewed papers for several national and international conferences and also for several journals which include IEEE Transactions on Communication, IEEE Transactions on Computers, and Computer Networks Journal.

SECURITY IN LOCAL AREA NETWORKS

Deepinder P. Sidhu
Research and Development *
Burroughs Corporation
Paoli, PA 19301

(*) On January 1, 1983, Organization becomes part of System Development Corporation – A Burroughs Company

APPROACHES TO LOCAL NETWORK SECURITY

- *END-TO-END ENCRYPTION*
- *TRUSTED SOFTWARE*
  (Subject of this talk)
- *ENCRYPTION AND TRUSTED SOFTWARE*

REFERENCES

D. P. Sidhu and M. Gasser, "Design for a Multilevel Secure Local Area Network", MITRE Corp., MTR-8702 (March 1982)

D. P. Sidhu and M. Gasser, "A Multilevel Secure Local Area Network", *Proc. of 1982 Security and Privacy Symposium*, Oakland, CA (26-28 April 1982)

D. P. Sidhu, "A Local Area Network Design for Military Applications", To be presented at the *7th Conference on Local Area Networks*, Minneapolis, MN (October 12-13, 1982)

D. P. Sidhu, "Security in Local Area Networks", Burroughs Corp. Report (1982), in preparation

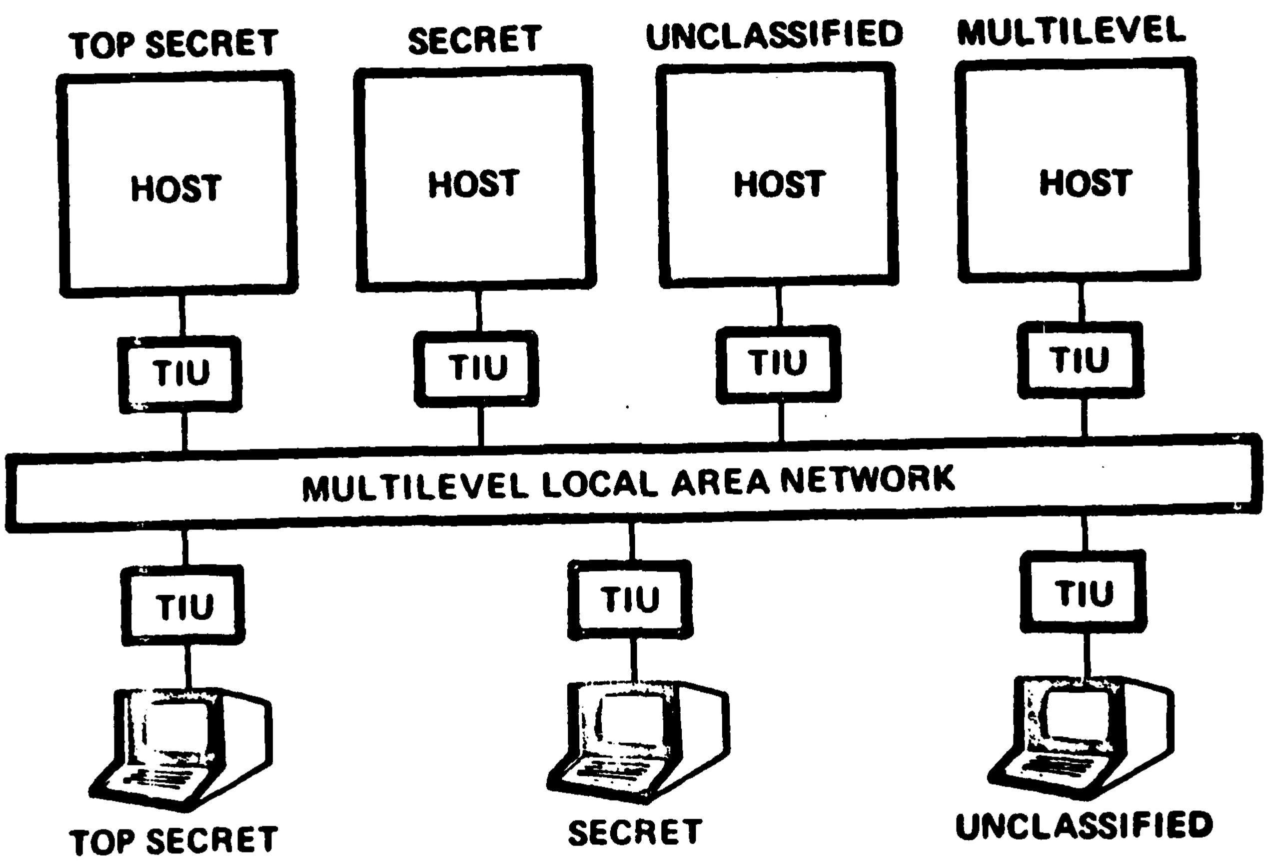


Figure Simple Multilevel Local Area Network

SECURE LAN REQUIREMENTS

Basic Requirement

LAN allows transmission of data at different security levels but with appropriate protection of data at each security level

Additional Requirements

1. *Flexibility to meet different operational requirements*

2. *Allows communication among subscribers fully consistent with DoD security policy*

3. *Flexibility to allow evolutionary changes - advances in transmission technology, VLSI hardware, etc.*

4. *Allows interconnection with wide-area networks*

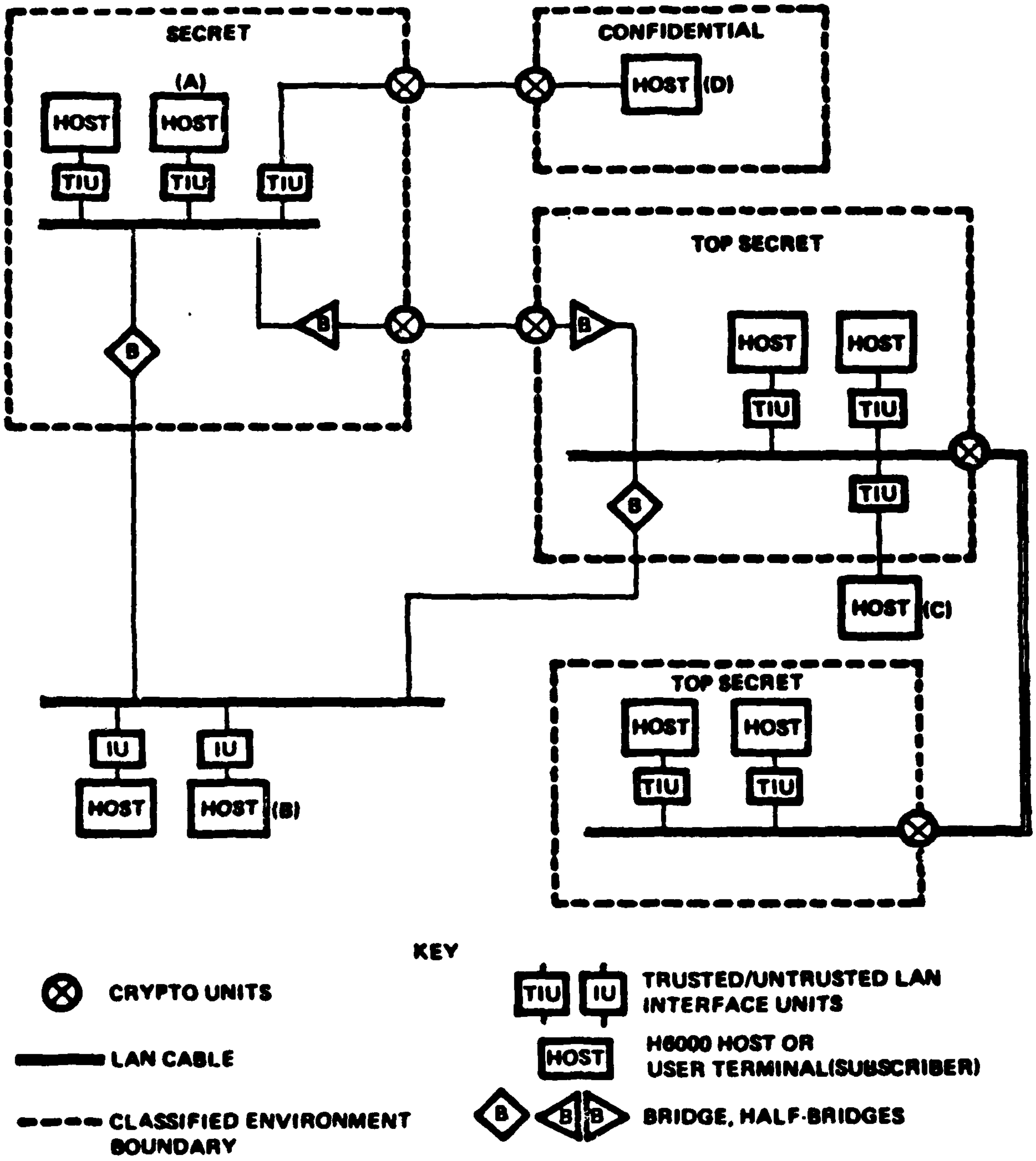


Figure   Full Multilevel Local Area Network

BENEFITS OF SECURE LAN ARCHITECTURE

1. *It allows reconfiguration with minimum disruption of service within a fixed security environment.*

2. *It allows user separation by communities of interest and information flow, as well as by security levels.*

3. *It allows for data security by physical separation of data flow if desired.*

4. *It enhances reliability by limiting the effect of failures and denial-of-service attacks to a single subnetwork.*

SECURE LAN COMPONENTS

- *Subnetworks*

  Parts of secure LAN that reside fully within protected security environments

- *Trusted Interface Units (TIUs)*

  Provide subscribers connection to subnetworks and act as security filters

- *Bridges*

  Provide links between subnetworks

- *Gateways*

  Allow interconnection to wide-area networks

- *Guards*

  Allow information to move from one security level to another in a controlled way

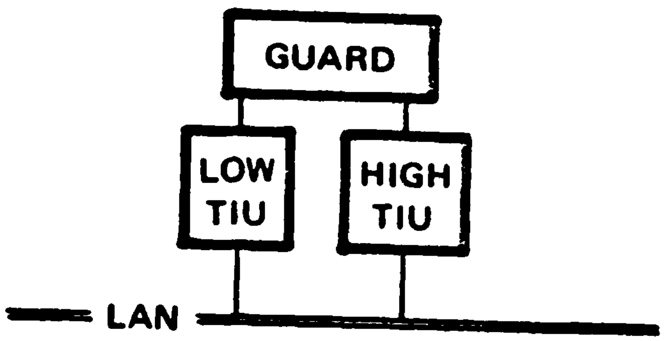


Figure Guard on the Secure LAN

SUBNETWORKS

- *TOPOLOGIES*
  - *Bus*
  - *Star*
  - *Ring*
  - *Mesh*

- *ACCESS METHODS*
  - *Random Access Protocols (e.g. CSMA/CD)*
  - *Broadcast Recognize Access Protocols*
  - *Token Passing Protocols*
  - *Dedicated Circuits*

- *TRANSMISSION TECHNIQUES*
  - *Baseband*
  - *Broadband*

SIMPLIFYING ASSUMPTIONS FOR SUBSEQUENT DISCUSSION

Subnetworks are bus networks
Use identical protocols (IEEE 802 CSMA/CD)

PROTOCOL DETAILS

Low Layer Protocols

Level 1:	*Physical*	*(IEEE 802)*
Level 2:	*Link*	*(IEEE 802 CSMA/CD)*
Level 3:	*Network*	

High Layer Protocols

Internet Protocol (IP)
Transmission Control Protocol (TCP)
(DoD Standard IP/TCP)

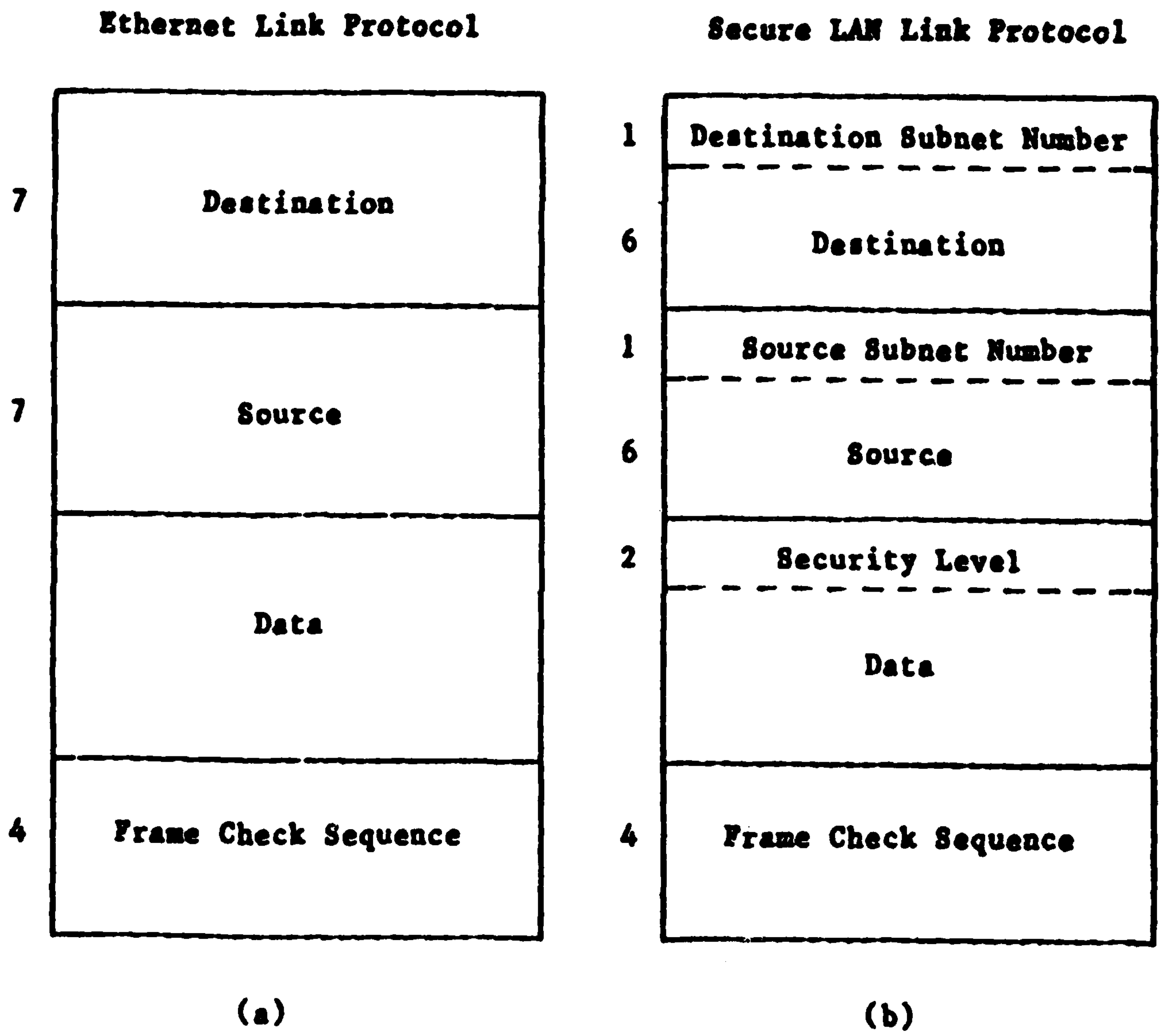


Figure Local Area Network Packet Format

FIELDS OF MODIFIED IEEE 802 CSMA/CD FRAME FORMAT

Destination Subnet Number: 1 octet
Destination local subnetwork number

Destination: 6 octets
Address on the subnetwork of the TIU receiving the frame

Source Subnet Number: 1 octet
Source local subnetwork number

Source: 6 octets
Address on the subnetwork of the TIU sending the frame

Security Level: 2 octets
Security level of the data part in the frame

Data: variable (up to some maximum) number of octets
Data in a fully transparent form, i.e., any bit sequence is allowed

Frame Check Sequence: 4 octets
Contains cyclic redundancy check (CRC) value computed over all the fields

CHANGES IN IEEE 802 FRAME FORMAT

- *Destination Subnet Number*
- *Source Subnet Number*
- *Security Level*
- *Use two-level hierarchical addressing scheme*
  Address = (Subnet Number, TIU Number)
- *Security Level Processing Function*

```
function Recognize_Security_Level
    (level: Security_Level_Value): Boolean
        begin
                Recognize_Security_Level :=
                {Return true if the level is a
                member of the set of secu-
                rity levels associated with
                the receiving unit}
        end; {Recognize_Security_Level}
```

ENCODING OF SECURITY LEVELS

- *Can specify a number of security levels with 16 bits*

- *A scheme* [Postel81/IP Spec] *to use 16 bits to specify 16 security levels*

00000000	00000000	-	Unclassified
11110001	00110101	-	Confidential
01111000	10011010	-	EFTO
10111100	01001101	-	MMMM
01011110	00100110	-	PROG
10101111	00010011	-	Restricted
11010111	10001000	-	Secret
01101011	11000101	-	Top Secret
00110101	11100010	-	(Reserved for future use)
10011010	11110001	-	(Reserved for future use)
01001101	01111000	-	(Reserved for future use)
00100100	10111101	-	(Reserved for future use)
00010011	01011110	-	(Reserved for future use)
10001001	10101111	-	(Reserved for future use)
11000100	11010110	-	(Reserved for future use)
11100010	01101011	-	(Reserved for future use)

DoD STANDARD INTERNET PROTOCOL (IP)

- *Provide Datagram service in the "catenet" environment*

- *Provide fragmentation and reassembly of long datagrams*

- *Security label of the datagram data field can be sent through the "option field" in IP header*

- *IP Header Format*

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version|  IHL  |Type of Service|          Total Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Identification        |Flags|      Fragment Offset    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time to Live |    Protocol   |         Header Checksum       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination Address                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Options                    |    Padding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

DoD STANDARD TRANSMISSION CONTROL PROTOCOL (TCP)

- *Connection oriented host-to-host protocol*
- *Provide reliability, flow control, multiplexing, ...*
- *Security label of data passed as parameter in TCP/IP interface calls (send and receive datagrams)*
- *TCP/User Connection "OPEN" Command*

  OPEN (local port, foreign socket, active/passive [, timeout][, precedence][, security/compartment][, options] -> local connection name

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Source Port          |       Destination Port        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Acknowdledgment Number                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Data |           |U|A|P|R|S|F|                               |
| Offset| Reserved  |R|C|S|S|Y|I|            Window             |
|       |           |G|K|H|T|N|N|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Options                    |    Padding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             data                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

TRUSTED INTERFACE UNIT DESIGN

- *Single-Level TIU*
  - *Figure*
  - *"Red/Black" refer to multilevel/single-level*
  - *Red Area*
    - *LAN medium*
    - *Interface*
    - *CSMA/CD*
    - *Security Processor*
  - *Black Area*
    - *CPU*
    - *Memory*
    - *I/O Ports*
- *Variable-Level TIU*
- *Multi-Level TIU*

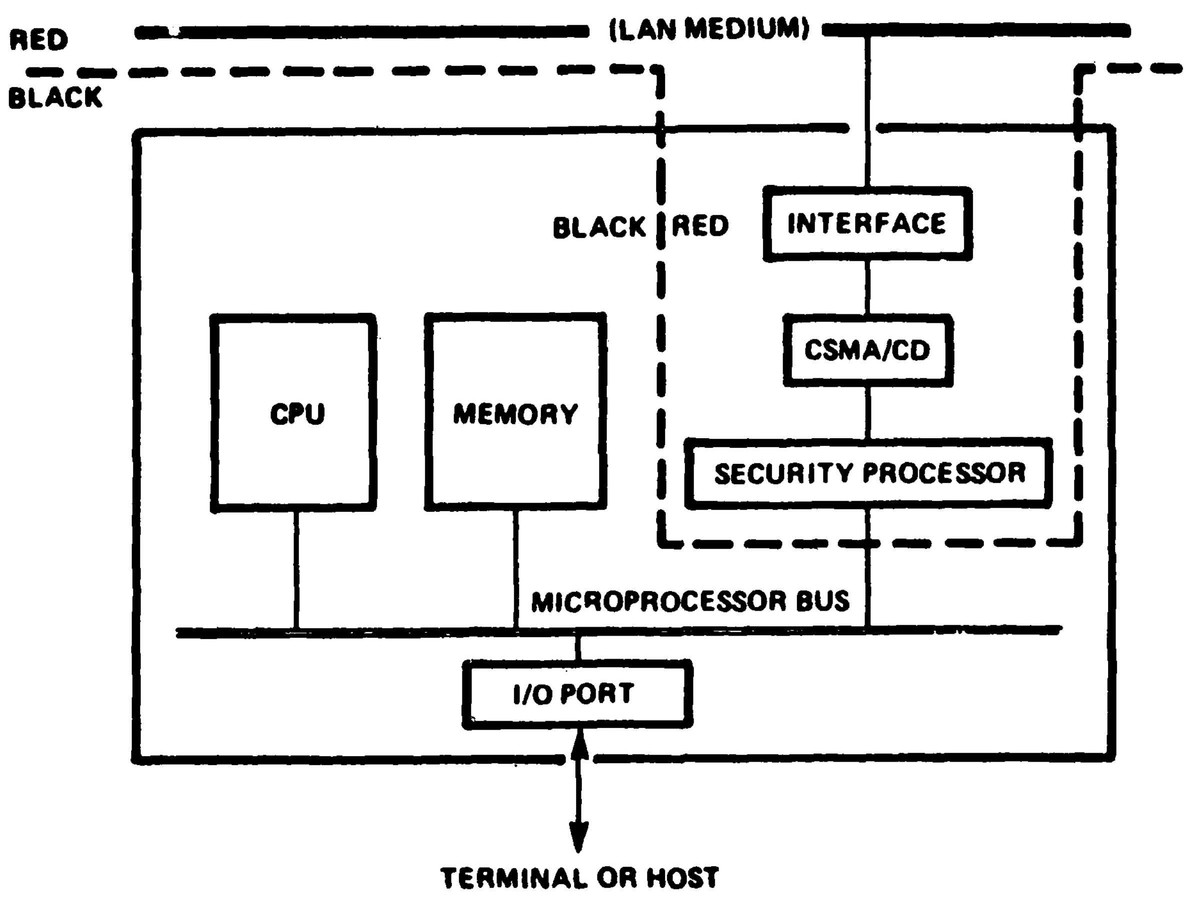


Figure **Trusted Interface Unit (TIU) Architecture**

SECURITY LABEL CHECKER FOR PACKETS

- *Feasible to implement hardware-validation mechanism for security labels on packets with a controlling state machine in the LAN interface*

BRIDGE CONCEPTS

- *Bridges pass in general multilevel data from one multilevel subnetwork to another which requires them to be trusted*
- *(Figure) shows logical structure of a bridge*
- *Bridges implement physical and link level protocols (also IP)*
- *Bridge Security Processing Function*
- *Bridges Implement Suitable Routing Strategy*
- *Bridge Provide Buffering Capability*
- *Half-Bridge Concept Useful*

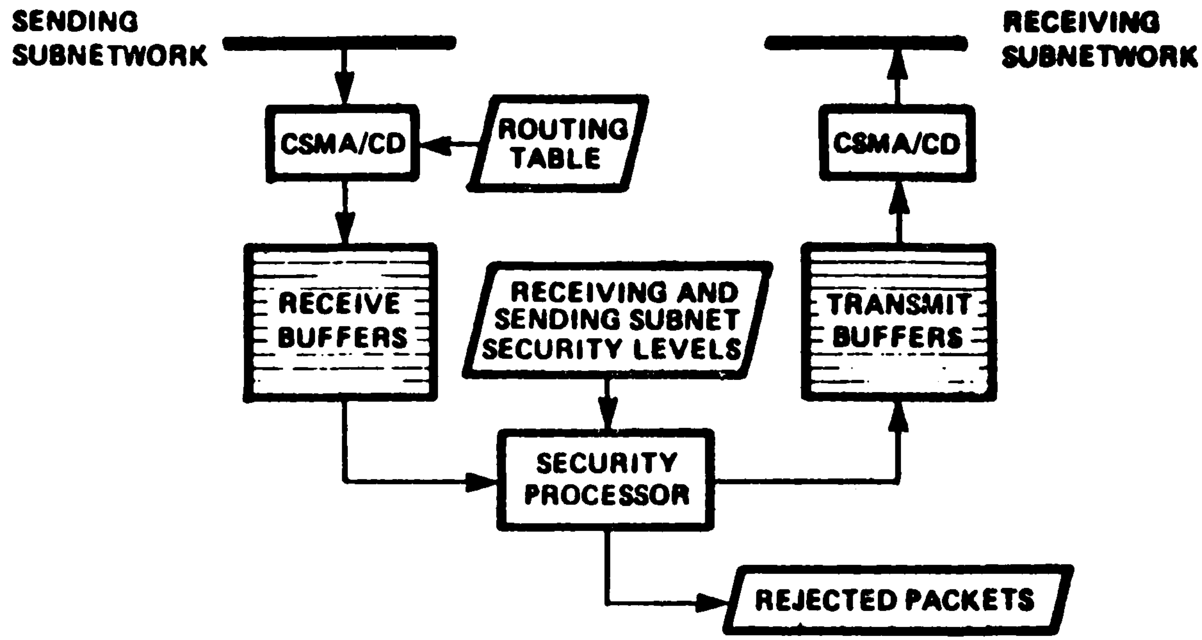


Figure Functional Bridge Architecture (Half-duplex)

(a)

LOCAL NETWORK # 1	2	3	4	5
1	1	0	1	0

1 (0) in column n means that bridge will (not) pick packets destined for subnetwork n.

(b)

BRIDGE # \ LOCAL NETWORK #	1	2	3	4	5
1	1	1	0	0	0
2	1	0	1	1	1
3	0	1	1	1	1
4	1	1	1	1	1
5	1	1	1	1	1

Figure   Fixed Routing Tables in Bridges

DESIGN ISSUES FOR FURTHER STUDY

- *Allowing multicast addressing make bridge design complex*
- *Bridges could become bottlenecks. IP in bridges could help alleviate congestion.*
- *Bridges introduce extra delay*
- *Alternatives to hierarchical addressing*
- *Mixing trusted software with end-to-end encryption*
- *Add security watch functions*
- *Allow one way communication*
- *Prevention of denial of service threats*
- *Distributed Operating System for LAN*
  - *Provide resource sharing*
  - *Provide administrative and maintenance functions*

LIMITATION AND RESTRICTIONS

- *Implementation of Need-to-Know protection will add considerable complexity to TIU in terms of trusted software*
- *TIU will require external databases to determine users identities (authentication)*
- *Overall security of data in the subnetwork depend on ability to physically protect the LAN medium*
- *Reconfiguration Difficult*

ALTERNATIVE APPROACHES TO LAN SECURITY

- *Use of Fixed Bandwidths*

  Assign information of different security levels (on a broadband cable) to different channels or time slots

  Disadvantages:
  Puts small upper bound on the number of security levels
  Requires cross channel bridges for upgade to full multilevel

- *Use of End-to-End Encryption*

  Key distribution problem

- *Use of Separate Physical LANs*

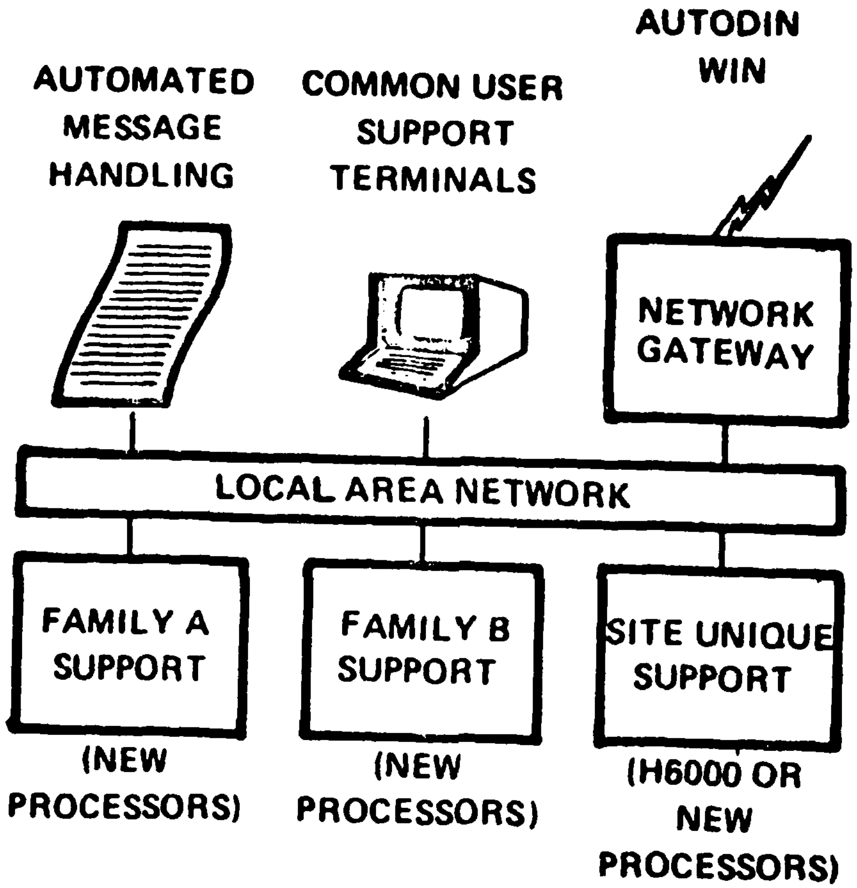


Figure Resources at a WIS Node

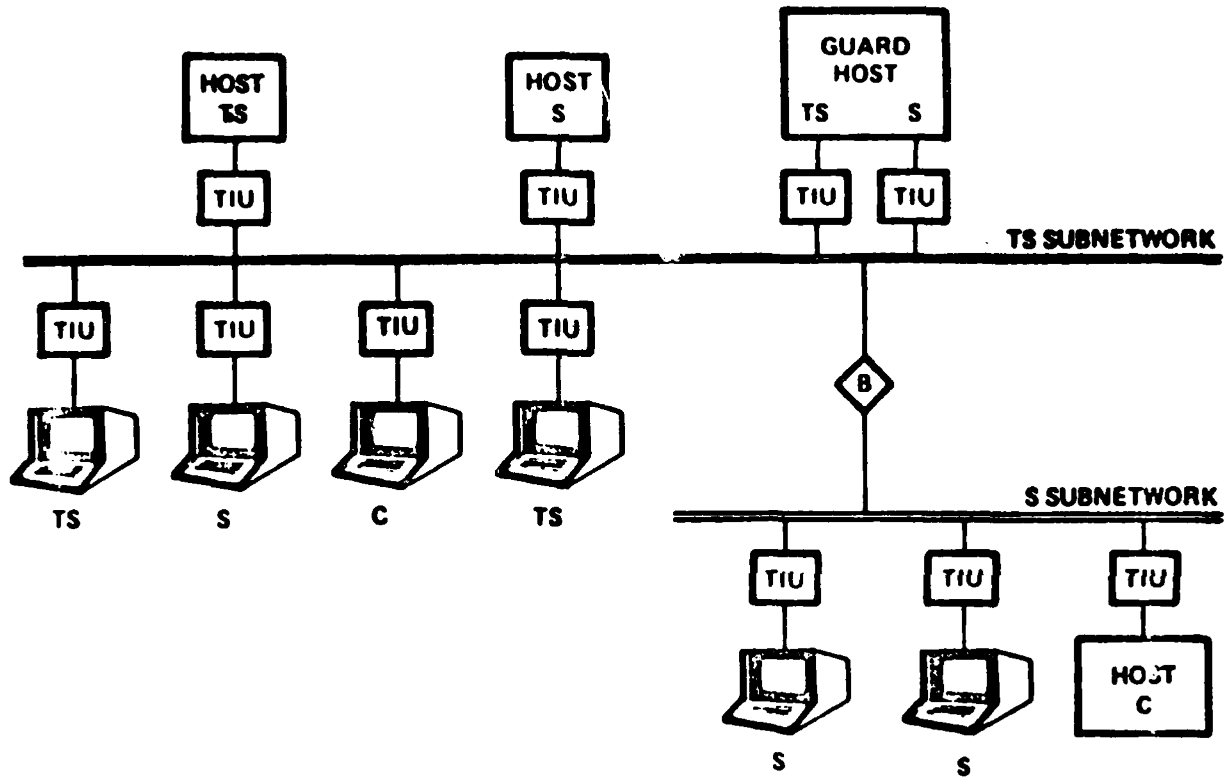


Figure Scenario #1: Single-level TIUs

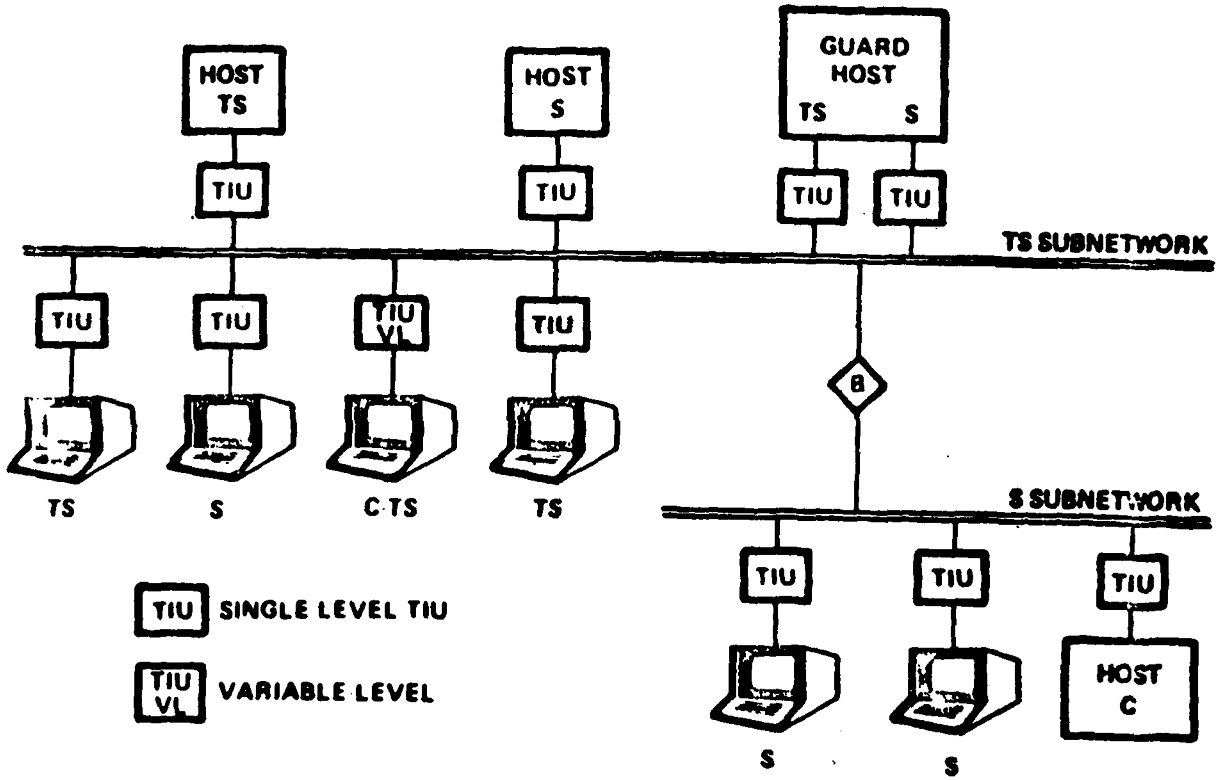


Figure Scenario #2: Variable-level TIUs

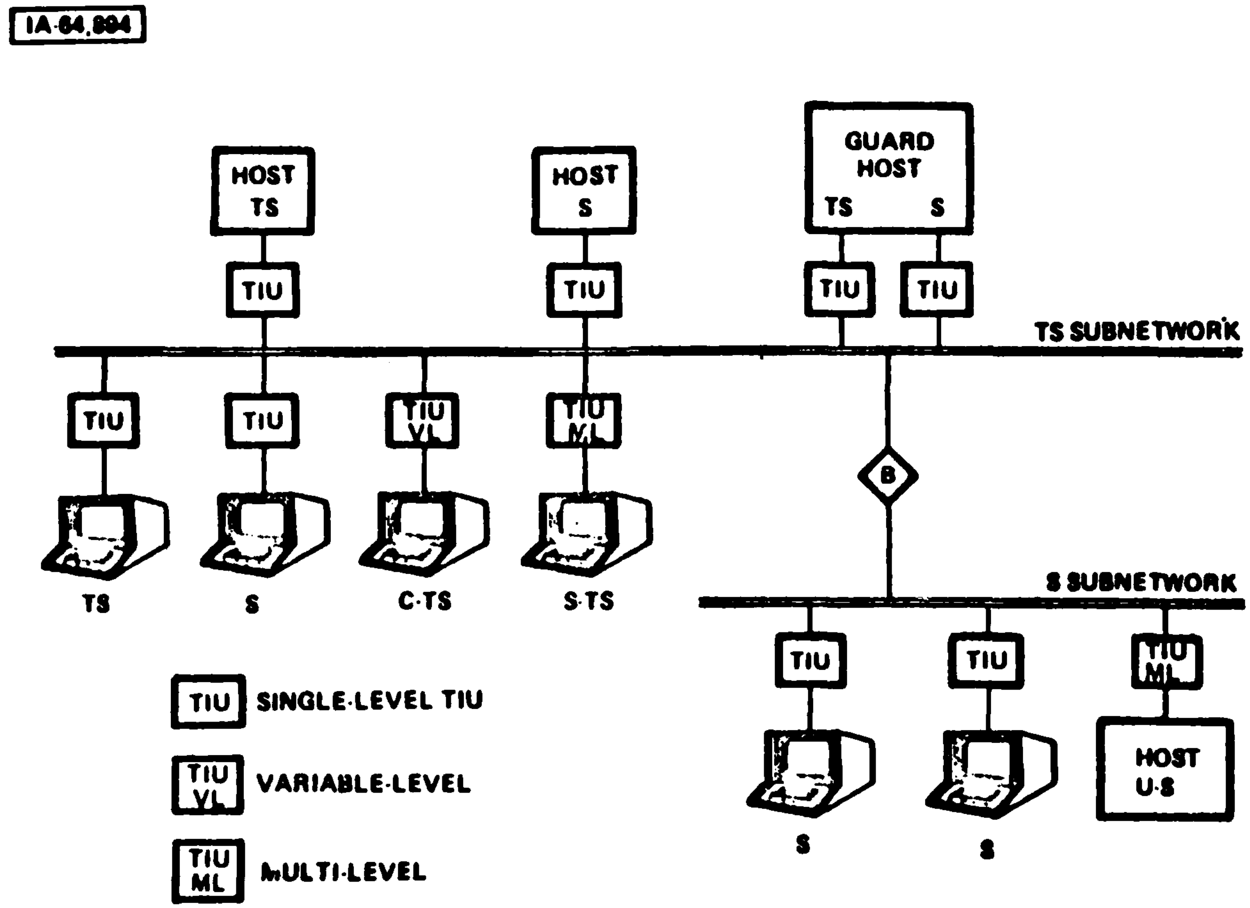


Figure Scenario #3: Variable and Multilevel TIUs

DESIGN TRADE-OFFS FOR SURVIVABLE LOCAL PACKET NETWORKS

JAMES A. KEDDIE

WHAT THIS TALK IS ABOUT

- SURVIVABILITY DESIGN ISSUES
- TRADE-OFFS
- DESIGN PHILOSOPHY
- IMPLEMENTATION EXAMPLES

WHAT THIS TALK IS <u>NOT</u> ABOUT

- A SURVIVABLE DESIGN RECOMMENDATION
- AN ALL INCLUSIVE DISCUSSION
- A SECURITY DISCUSSION

DEFINITIONS

- SYSTEMS ENGINEERING
- LAYERED ARCHITECTURE
- LOCAL AREA NETWORK
- SURVIVABILITY

SYSTEMS ENGINEERING

- REQUIREMENTS DEFINITION
- ANALYSIS
- TRADE-OFFS/SELECTION
- DESIGN/SPECIFICATION
- IMPLEMENTATION
- VERIFICATION/VALIDATION

Protocol Hierarchical Structure

LAYER	LEVEL	PURPOSE	DATA UNIT
Application	7	To provide the means for applying distributed data communications/ processing resources to specific user requirements.	Message
Presentation	6	To provide means for transforming data including data compression, code conversion, file format conversion, and data terminal presentation changes.	Message
Session	5	To provide users the means to open and close connections, negotiate service options, and control data transmission.	Message
Transport	4	To provide the means for reliable communications between host processes including establishing, managing, and multiplexing connections and regulating data flow.	Message
Network	3	To provide the means to reliably exchange data and control information with the communications subnet.	Packet
Data Link	2	To define the means for exchanging data over a communications link, including error control and data flow regulation.	Frame
Physical	1	To define the physical, electrical, functional, and procedural characteristics to establish, maintain, and disconnect the physical communications link.	Bit

LOCAL AREA NETWORK

- TRANSMISSION MEDIA INEXPENSIVE
- HIGH DATA RATES
- HIGH CONNECTIVITY
- NODES CAN COMMUNICATE DIRECTLY
- DATA FORMATED IN PACKETS

SURVIVABILITY

PROVIDE SERVICE TO SURVIVING SUBSCRIBERS DURING A DISASTER WHICH RENDERS SOME SWITCHING CENTERS INOPERATIVE

THE CAPABILITY TO PERMIT CRITICAL MESSAGE TRAFFIC TO FLOW IN SPITE OF THE SIMULTANEOUS DISABLEMENT OF MULTIPLE LINKS AND NODES WITHIN THE NETWORK AND THE INTRODUCTION OF JAMMING AND SPOOFING SIGNALS BY AN ADVERSARY

SURVIVABILITY

THE ABILITY OF A NETWORK TO SUSTAIN DAMAGE AND CONTINUE TO PROVIDE AN ACCEPTABLE LEVEL OF SERVICE TO THE SUBSCRIBERS OF THE NETWORK

NETWORK SURVIVABILITY FEATURES

- MULTIPLE ROUTES
- ROUTING EFFICIENCY
- DISTRIBUTED INTELLIGENCE
- ENVIRONMENTAL RESISTANCE
- PROTOCOLS

MULTIPLE ROUTE FEATURES

- NUMBER OF LINKS TO EACH NODE
- DISPERSION OF LINKS
- TOPOLOGY OF TRANSMISSION MEDIA
- MULTIPLE TRANSMISSION MEDIAS

ROUTING EFFICIENCY FEATURES

- SELECTS SHORTEST ROUTE
- AUTOMATIC REROUTING
- AUTOMATIC DATA FORMAT CONVERSION
- CONGESTION CONTROL

DISTRIBUTED INTELLIGENCE FEATURES

- AUTONOMOUS NODE CONTROL
- AUTOMATIC RECOVERY/RECONFIGURATION
- MULTIPLE NETWORK MANAGERS
- REDUNDANT ACCESS CONTROL SITES
- REDUNDANT KEY DISTRIBUTION MANAGER SITES

ENVIRONMENTAL FEATURES

- RADIOACTIVE HARDENING
- TEMPEST TESTING
- MILITARIZED (SHAKE, RATTLE, & ROLL)
- SHIELDING

PROTOCOL SURVIVABILITY FEATURES

- ERROR CONTROL
- MESSAGE ACCOUNTABILITY
- MALFUNCTION DETECTION
- ADVERSARY DETECTION

SURVIVABILITY MUST BE DESIGNED IN

- THREATS DEFINED
- SURVIVABILITY AND EFFICIENCY GOALS DEFINED
- DESIGN TECHNIQUES EMPLOYED

THREAT DEFINITION YIELDS USER SURVIVABILITY REQUIREMENTS

- EXTERNAL THREATS
  - ELECTRONIC WARFARE
  - DIRECTED ENERGY
  - PHYSICAL
- INTERNAL THREATS
  - FAILURES
  - PROCEDURAL ERRORS
  - EMPLOYEE SABOTAGE

GOALS AND OBJECTIVES YIELD MEASUREABLE CONSTRAINTS

- ADDRESSING
- ROUTING
- EFFICIENCY
- PERSISTENCE
- AVAILABILITY
- RELIABILITY

DESIGN TECHNIQUES EMPLOYED DIRECTLY INTO A SYSTEMS ENGINEERING APPROACH

- FAULT TOLERANCE
- FAIL SAFE
- ERROR DETECTION CORRECTION
- SECURITY FAULT ANALYSIS
- VERIFICATION AND VALIDATION
- DISTRIBUTED PROCESSING

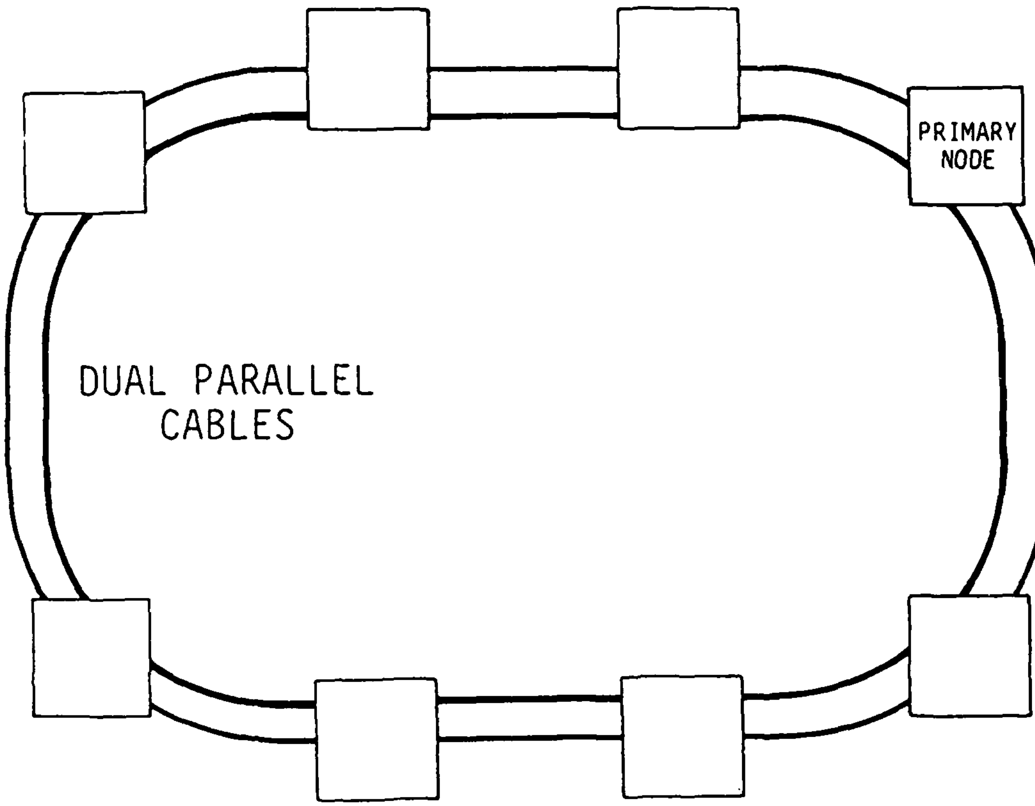
DESIGN OPTIONS

FEATURES (GOALS)	IMPLEMENTATION
MULTIPLE ROUTES	DOUBLE LOOP DESIGN
ROUTING EFFICIENCY	DECNET
DISTRIBUTED INTELLIGENCE	TOKEN PASSING
ENVIRONMENT HARDENING	PACKET RADIO NETWORK
PROTOCOLS	MULTILEVEL SECURITY PACKET NETWORK

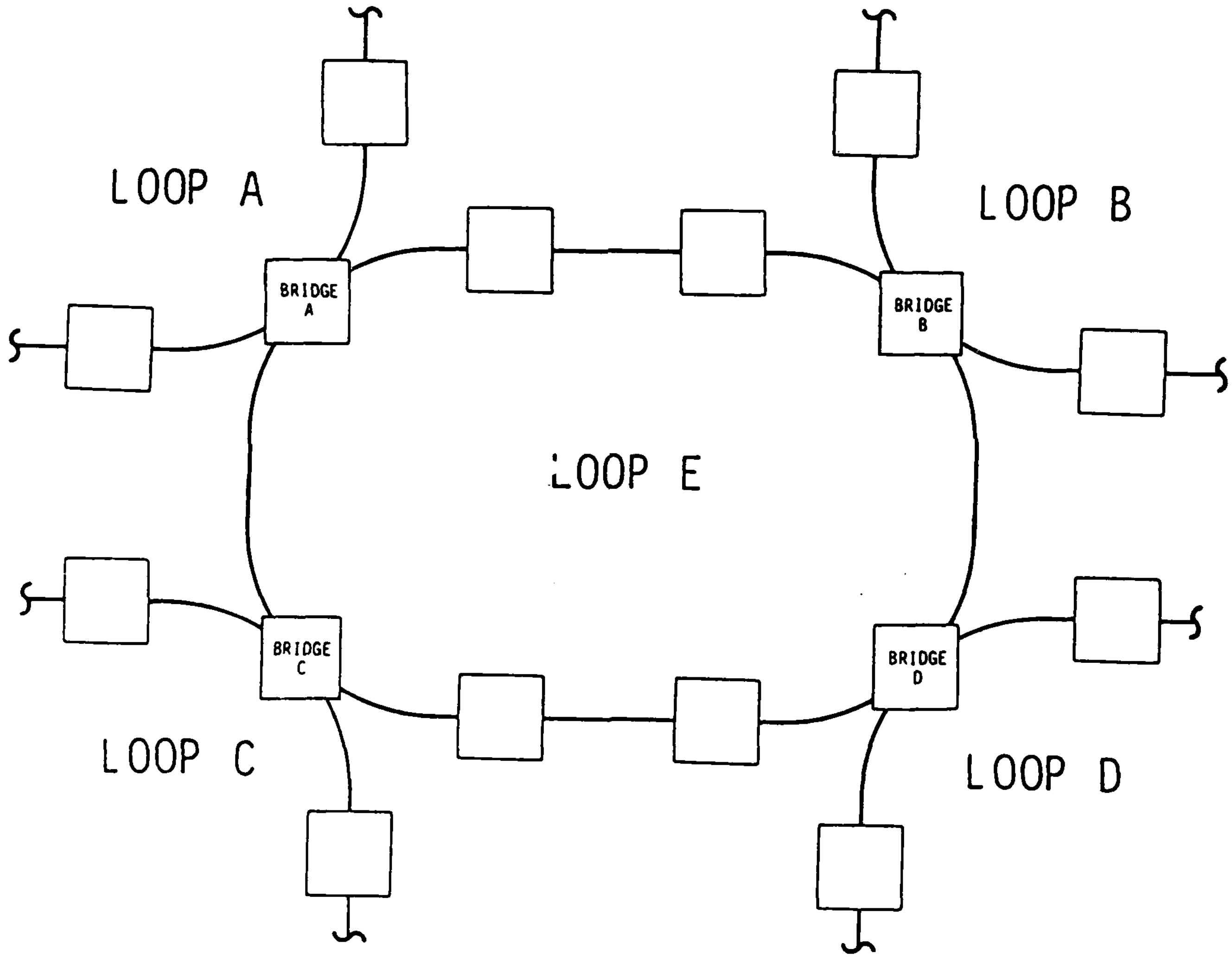
DESIGN TRADEOFFS ISSUES

- ROUTING ADAPTABILITY VS CAPABILITY
- ADDRESSING VS EXPANDABILITY
- SIMPLICITY VS CAPABILITY
- PERSISTENCE VS THROUGHPUT

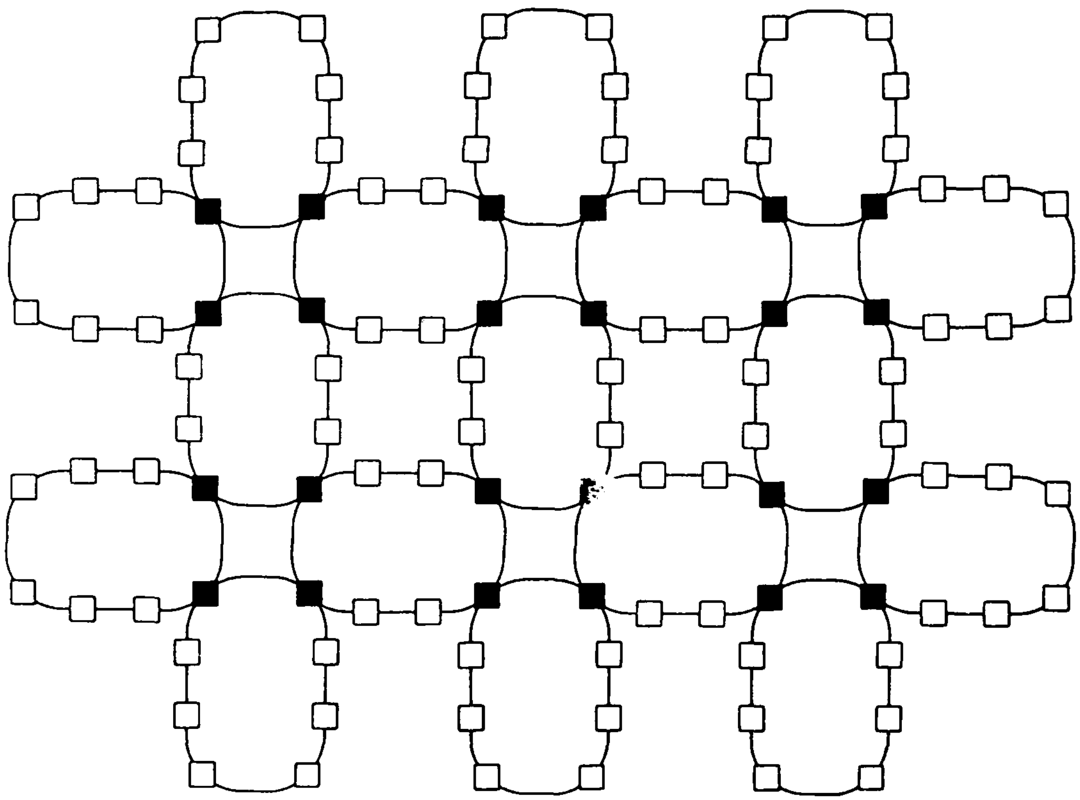
DOUBLE LOOP ARCHITECTURE



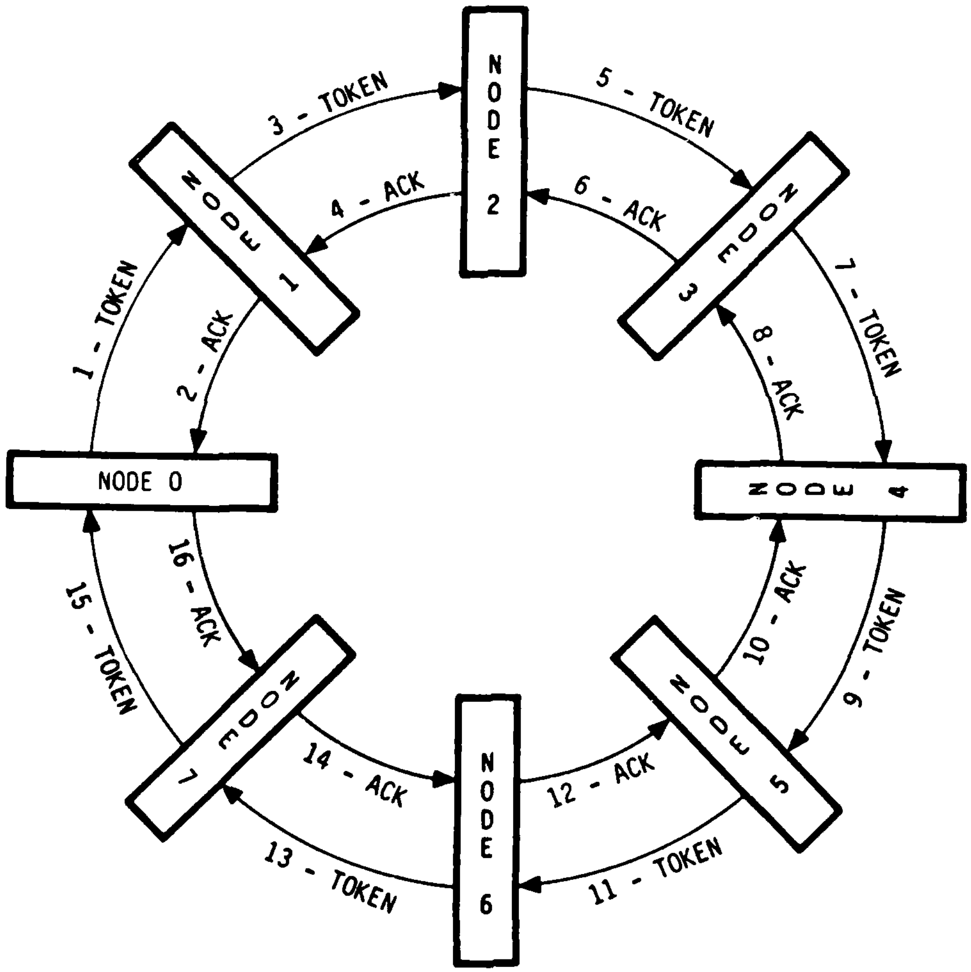
MULTIPLE DOUBLE LOOP ARCHITECTURE



FLAT FOUR DOUBLE LOOP

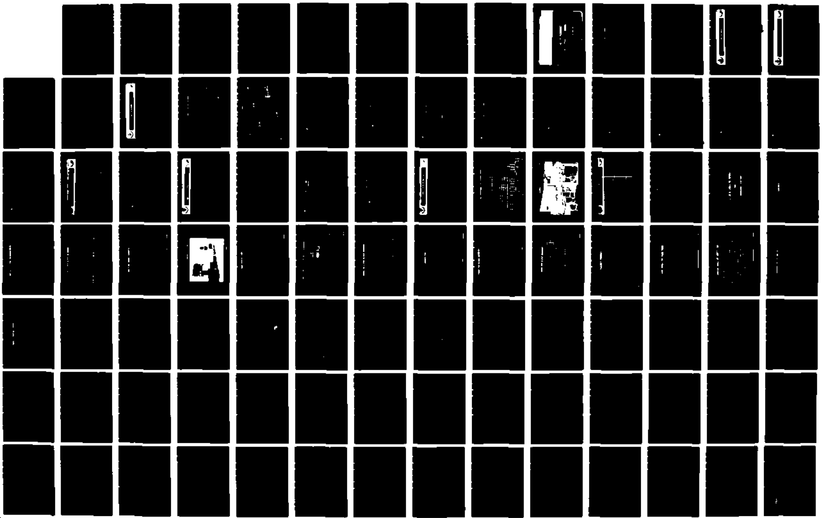


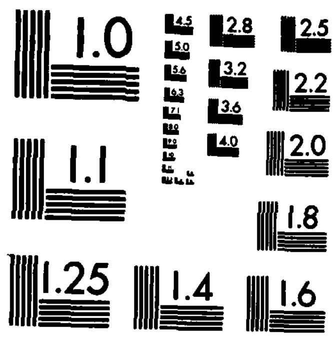
TOKEN PASSING



AD-A126 110 PROCEEDINGS OF CONFERENCE ON LOCAL AREA MILITARY NETWORKS GRIFFISS AFB NEW YORK 28-30 SEPTEMBER 1982(U) ROME AIR DEVELOPMENT CENTER GRIFFISS AFB NY D B WARMUTH ET AL. 1982 4/6

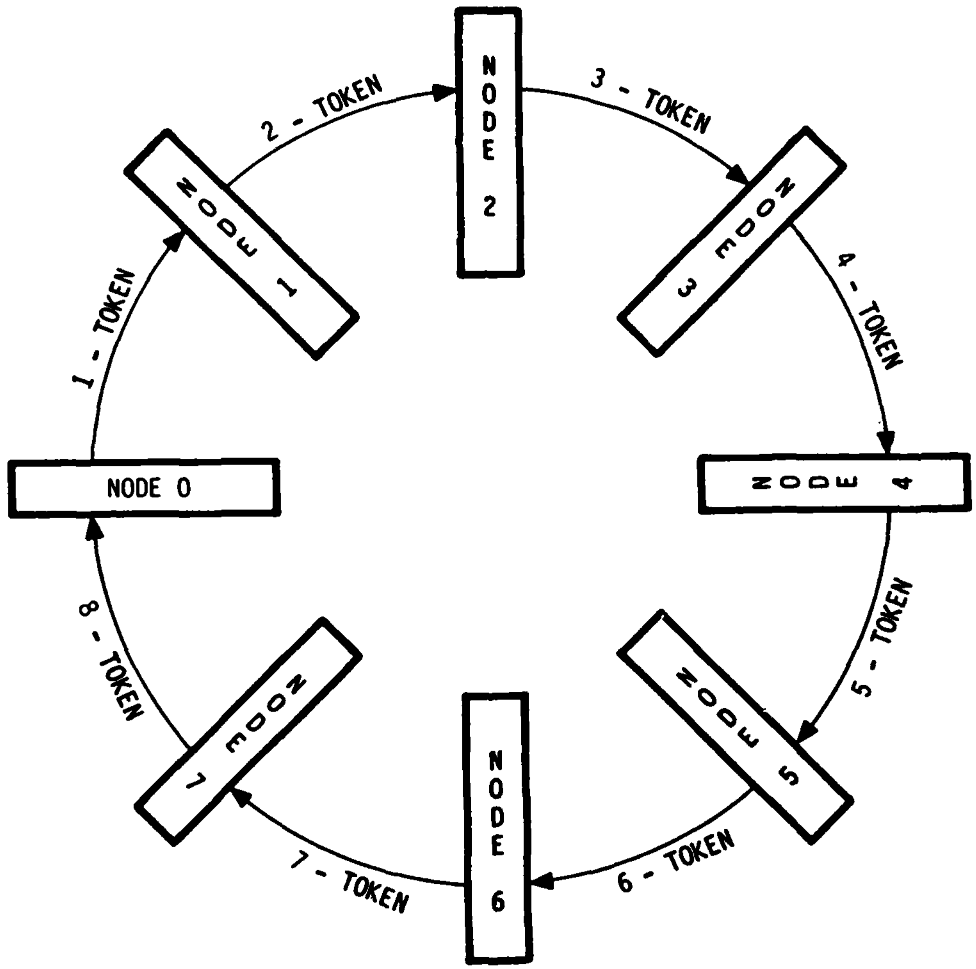
UNCLASSIFIED F/G 17/2 NL



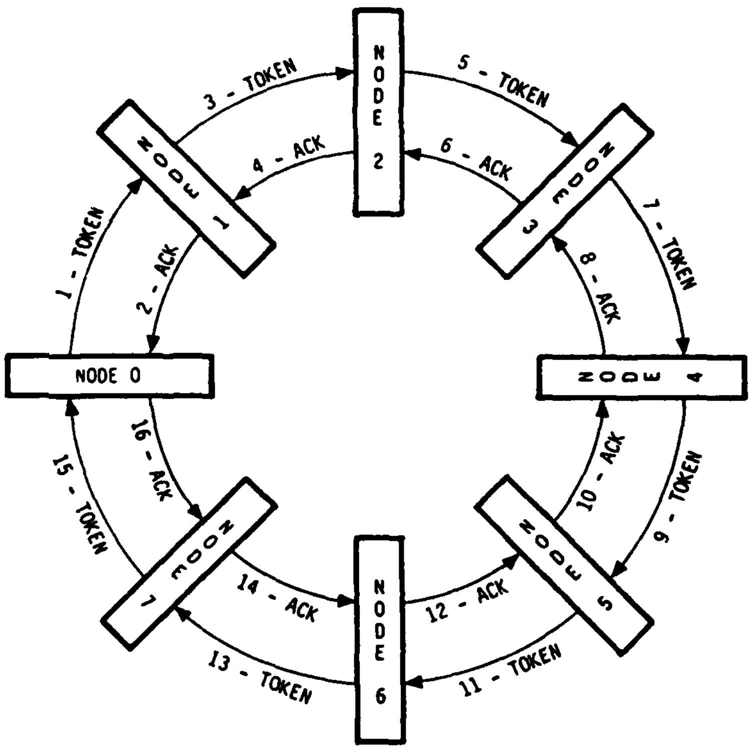


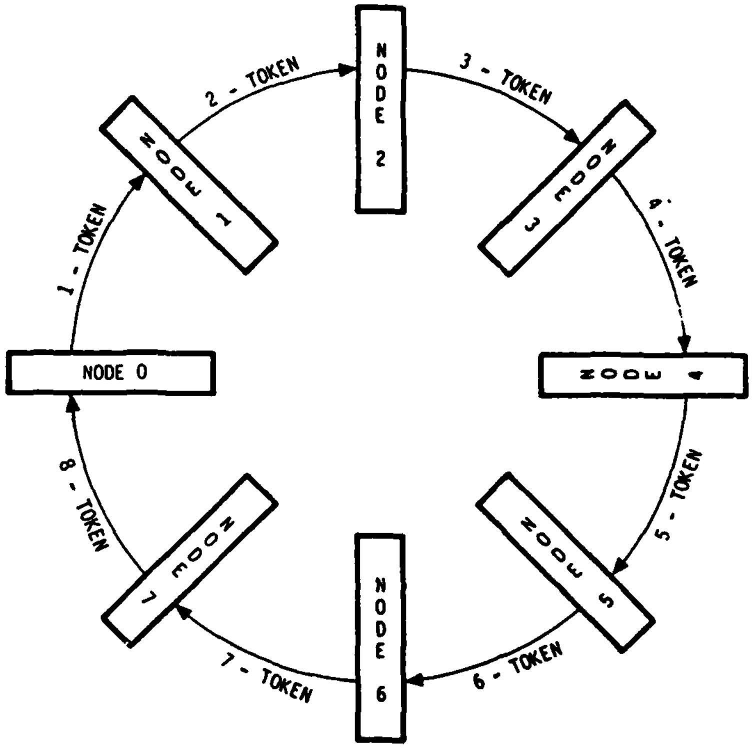
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TOKEN PASSING

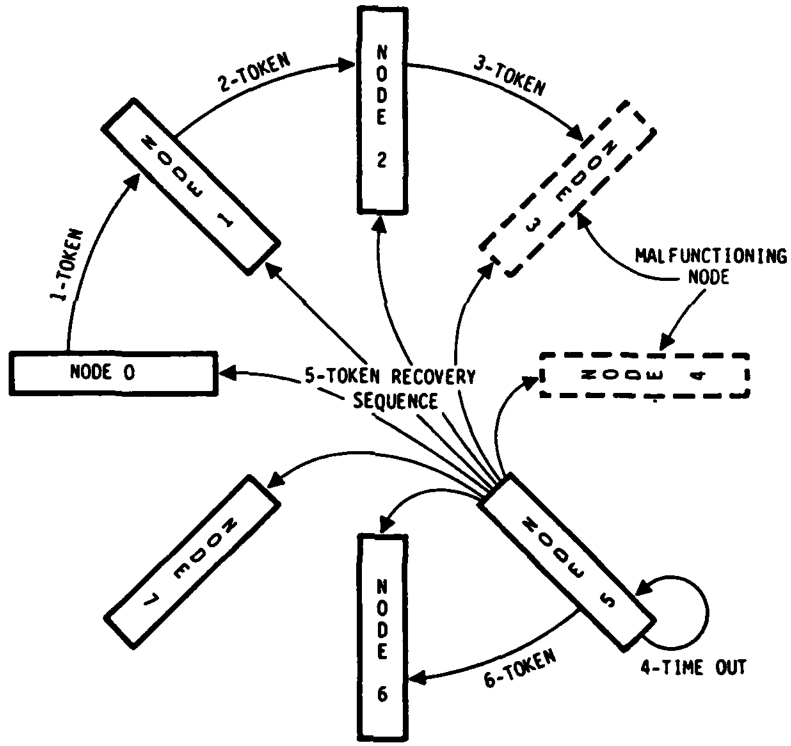


ADAPTABILITY VS EFFICIENCY

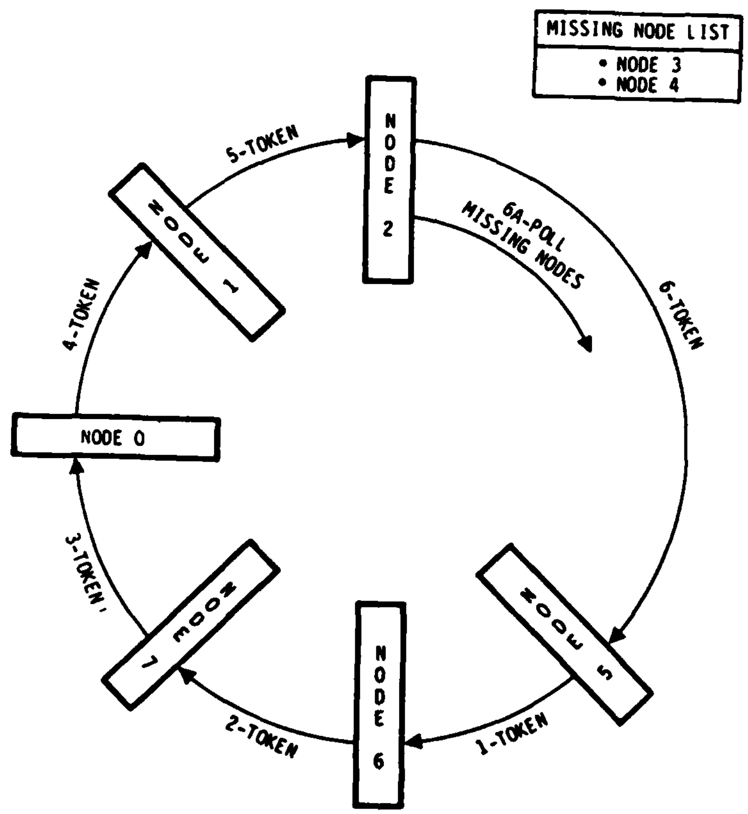




DISTRIBUTED MALFUNCTION AND TOKEN RECOVERY

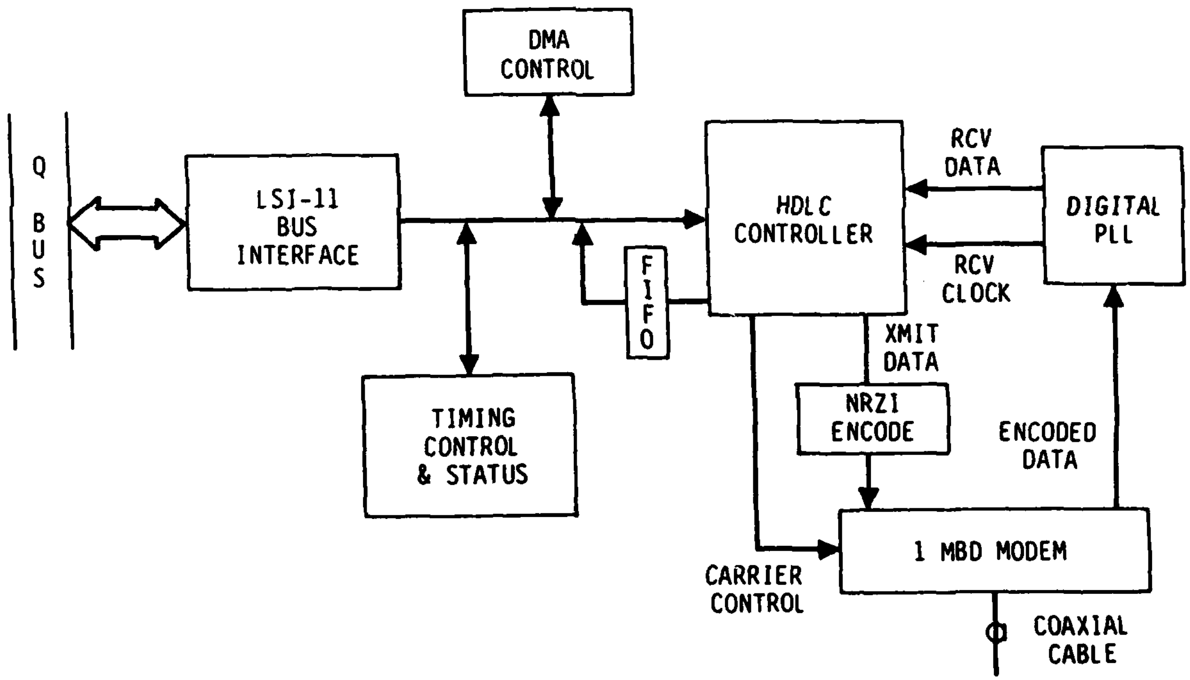


MISSING NODE RECOVERY



MEGALINK SYSTEM BLOCK DIAGRAM

LSI-11 1MBD COMMUNICATIONS INTERFACE



SURVIVABILITY MUST BE DESIGNED IN

- THREATS DEFINED
- SURVIVABILITY AND EFFICIENCY GOALS DEFINED
- DESIGN TECHNIQUES EMPLOYED

Implementation I (1400-1545 29 Sep)

Session Chairman: Mr. Brian Hendrickson - RADC/DCLW

"Flexible Interconnect Local Area Network," Mr. James L. Davis, Rome Air Development Center

Development of a general purpose high performance local area network for C3I will be described. Technical characteristics and program status will be discussed.

"Local Area network Design for Command Centers," Mr. Otis Gooding, Litton Amecom

Presentation describes the high speed LAN designed to meet the communication performance requirements of a command center complex. The LAN design provides an integrated communication network for voice, video, and data all combined into a single system. The system is capable of interconnecting a wide variety of telephone instruments, radio equipment, crypto devices, work stations, and other data devices. A highly transparent user interface and protocol inter connect is provided for maximum adaptation and flexibility. In addition to providing routine protocol handling, the interconnect architecture allows special processing of user information when required. Those features that best characterize the system performance are high throughput, high reliability, expandability and distributed network control.

"Application of Local Area Network to Navy Command Centers," Mr. Calvin Cornils, Naval Electronics System Engineering Center

The Navy (NAVELEX PME-120) is developing a prototype local data network for testing at its land based command and control test bed. Subsequent field testing in an operational environment is also planned. The network will be used to develop improvements in data exchange techniques (via gateways) to long haul communication circuits, and to demonstrate the applicability of local network technology to Naval command centers ashore.

"Fiber Optic Impact on Local Area Networks," Mr. Peter Steensma, ITT Defense Communications Division

System impacts of speed ranges available by fiber optics utilization will be discussed. Protocal issues, bandwidth and physical (distance) implication will also be discussed.

E-1

FLEXIBLE INTRACONNECT

NEW APPROACH TO C^3 CENTERS

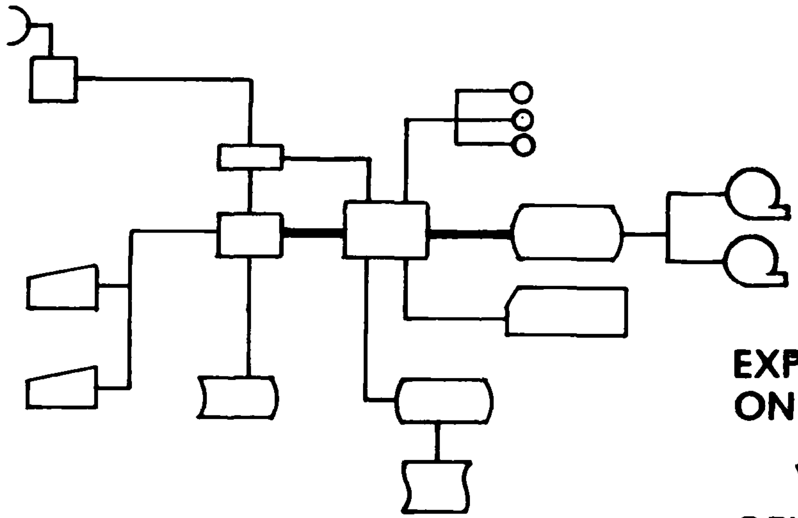
PRESENTED BY: JIM DAVIS, RADC/DCL

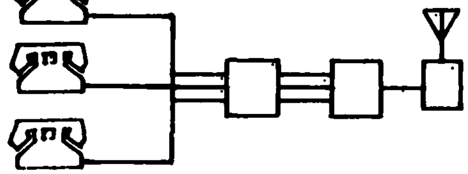
C^3 ACQUISITION ENVIRONMENT

LONG, INVOLVED PROCESS
TOO MUCH COST TO DEVELOP & TIME TO REALIZE
DYNAMIC REQUIREMENTS NOT SATISFIED
ACCELERATED TECHNOLOGICAL OBSOLESCENCE
INTENSE REAL-TIME OPERATIONAL SCENARIOS
LIMITED RECURRING OPERATIONAL EXPERIENCE

GOAL: DEVELOP CONCEPT TO STREAMLINE PROCESS

FLEXIBLE INTRACONNECT CONCEPT

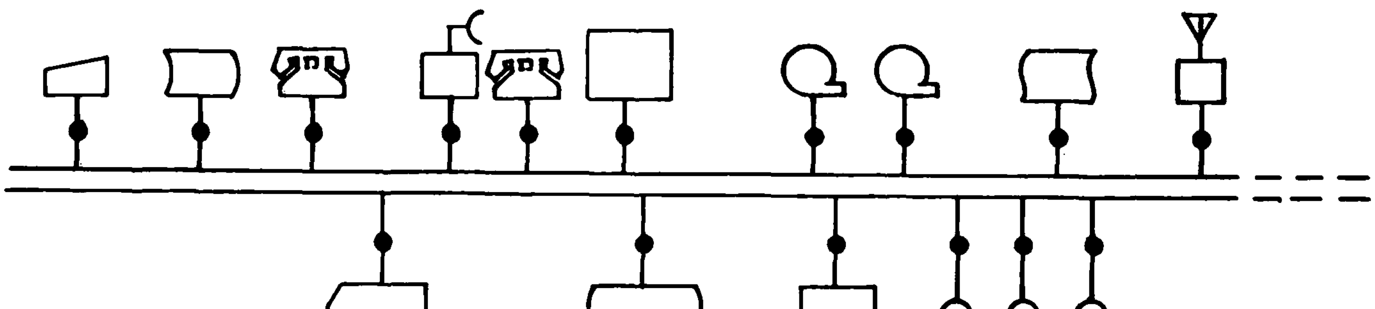




EXPLICIT
ONE-OF-A-KIND SYSTEMS

vs

GENERIC
MODULAR
ARCHITECTURE



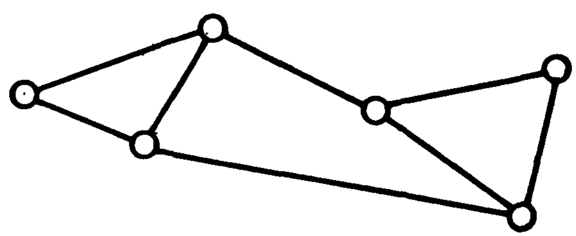
LOCAL AREA NETWORK

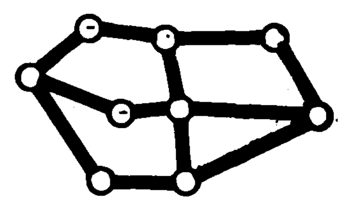
DEFINITION:

LOCAL	100 METERS TO 10 KM
AREA (EQUIPMENT)	COMPUTERS, TERMINALS, TELEPHONES, GRTS, WORK STATIONS, INSTRUMENTATION
NETWORK	CONNECTS 10 TO 10,000 STATIONS

COMMUNICATION TECHNOLOGIES

LONG HAUL NETWORK	LOCAL NETWORK
WIDE AREA, LOW BANDWIDTH	SMALL AREA, HIGH BANDWIDTH





(2KB\S X 5000Km = 10,000,000)

(2MB\S X 5Km = 10,000,000)

BANDWIDTH X DISTANCE = CONSTANT

LOCAL AREA NETWORKS

APPLICATION:	CHARACTERISTICS-ENVIRONMENT:
OFFICE AUTOMATION	TERMINAL ORIENTED-LIGHT INDUSTRY
PROCESS CONTROL	REAL TIME-HEAVY INDUSTRIAL
INSTRUMENTATION	PERIODIC SAMPLES-LABORATORY TESTING MIXED RATES
SPECIAL PURPOSE	IMBEDDED, CUSTOMIZED-VARIOUS (WEAPONS SYSTEMS)
COMMAND & CONTROL	REAL TIME, SURVIVABLE, FAULT TOLERANT, FILE TRANSFERS-SEVERE UNPREDICTABLE MILITARY ENVIRONMENT, MULTIPLE VENDORS

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LOCAL AREA NETWORKS

APPLICATIONS & SUGGESTED STANDARDS

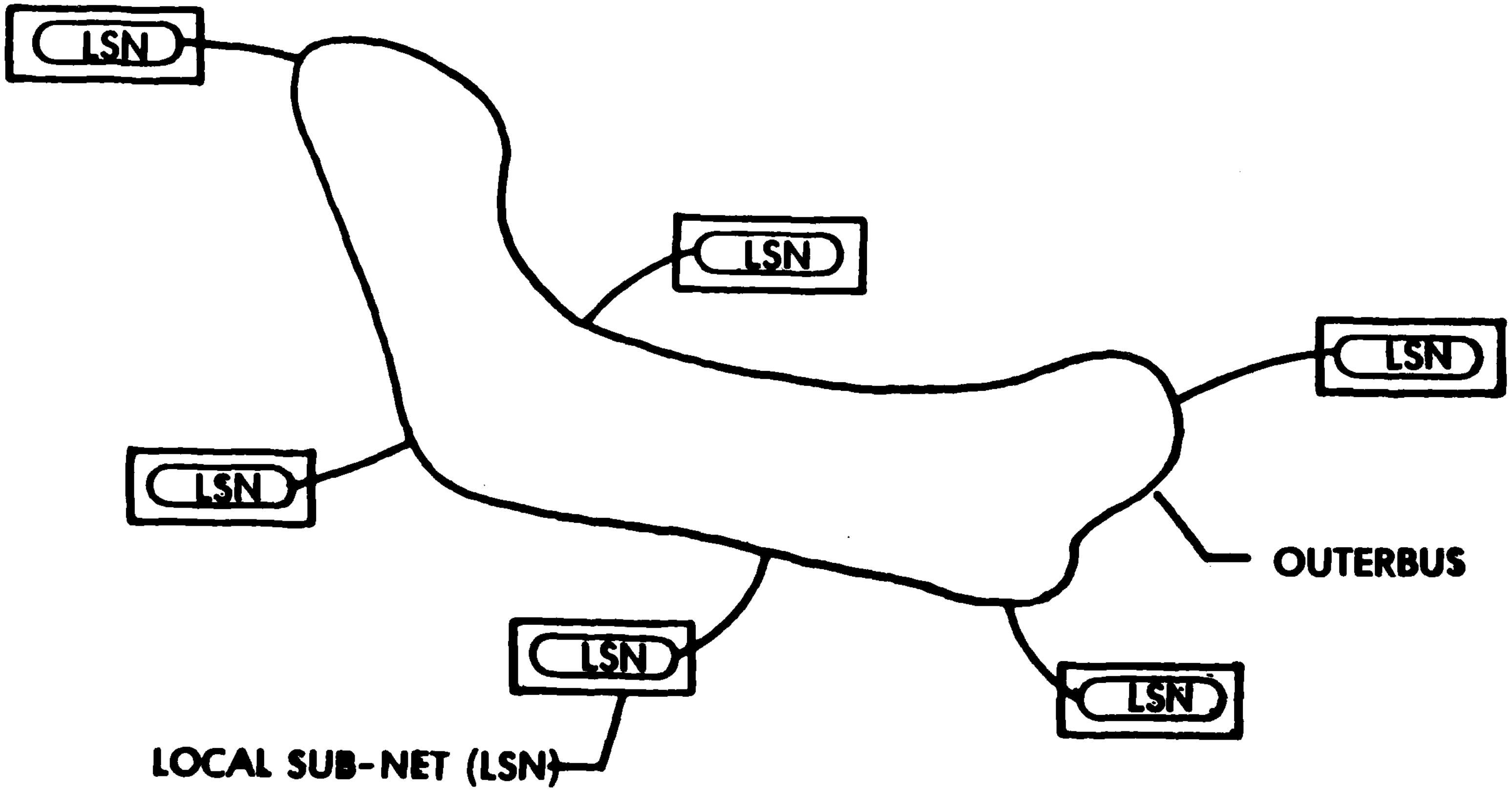
APPLICATION	STANDARD
OFFICE AUTOMATION/PROCESS CONTROL	IEEE-802 (ETHERNET)
INSTRUMENTATION SYSTEMS	IEEE-488
AVIONICS, VEHICLE CONTROL	MIL-STD-1553B
COMMAND & CONTROL	FLEXIBLE INTRACONNECT

FLEXIBLE INTRACONNECT

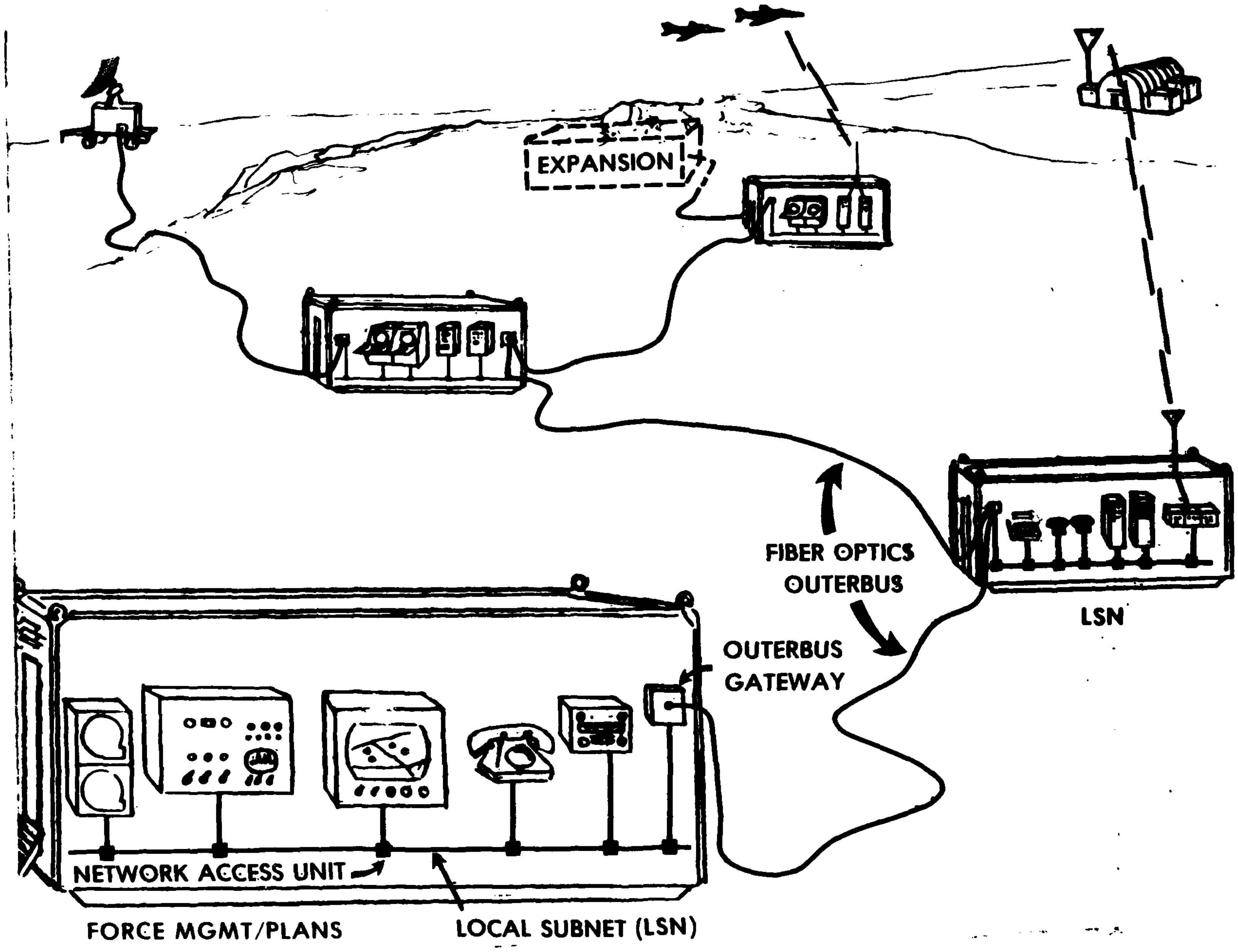
LOCAL INFORMATION DISTRIBUTION SYSTEM

- UNIFORM DIGITAL CONTROL
- GENERAL PURPOSE MILITARY APPLICATIONS
- HIGH CAPACITY
- HIGH INTEGRITY
- MODULAR & EXTENSIBLE

FLEXIBLE INTRACONNECT LOCAL AREA NETWORK



FLEXIBLE INTRACONNECT



FI SERVICES & FEATURES

ADDRESSING
ERROR CONTROL
GUARANTEED MESSAGE DELIVERY
REAL TIME CIRCUIT AVAILABILITY
VENDOR INDEPENDENCE
LINK ENCRYPTION (OBS/EFTO)

Change: "Addressing" to: "Flexible Addressing"

Delete: "Vendor Independence"

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FILAN ADDRESSING

- POINT-TO-POINT
- BROADCAST
- MULTICAST
- VIRTUAL ADDRESSING
  - MOMCOM (MAN ON THE MOVE)

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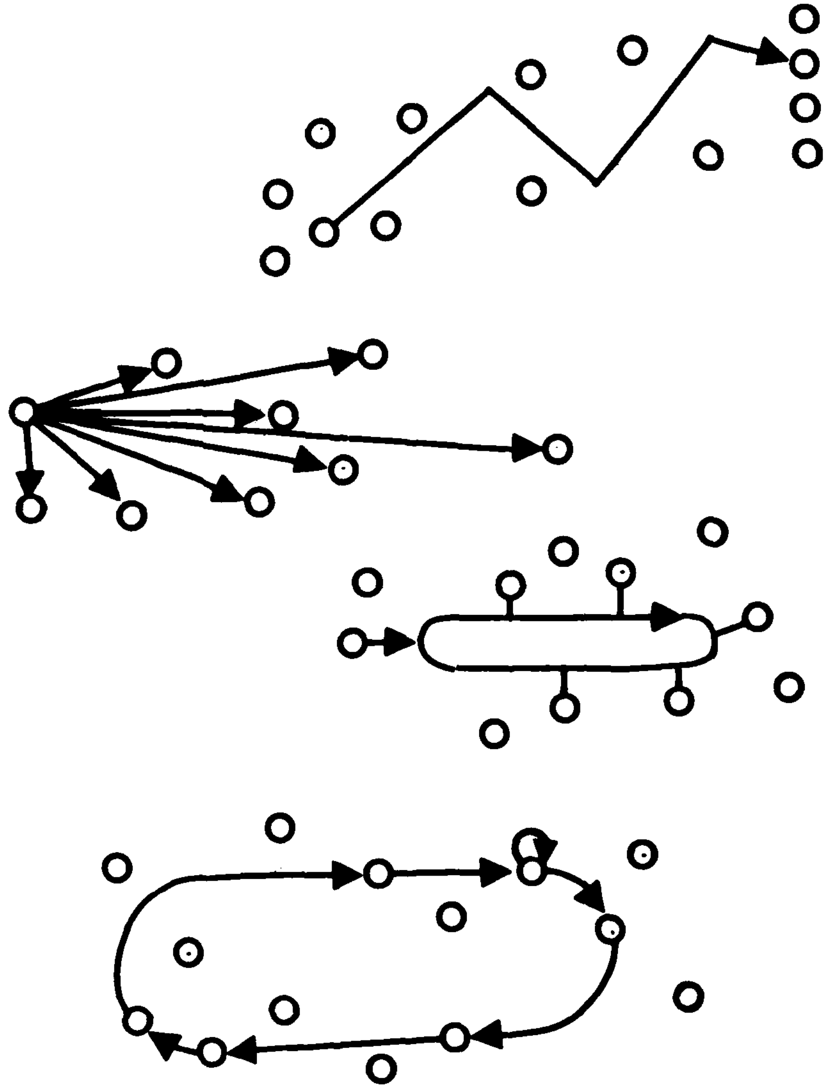
FI ADDRESSING SERVICES

POINT TO POINT
(ONE TO ONE)

BROADCAST
(ONE TO ALL)

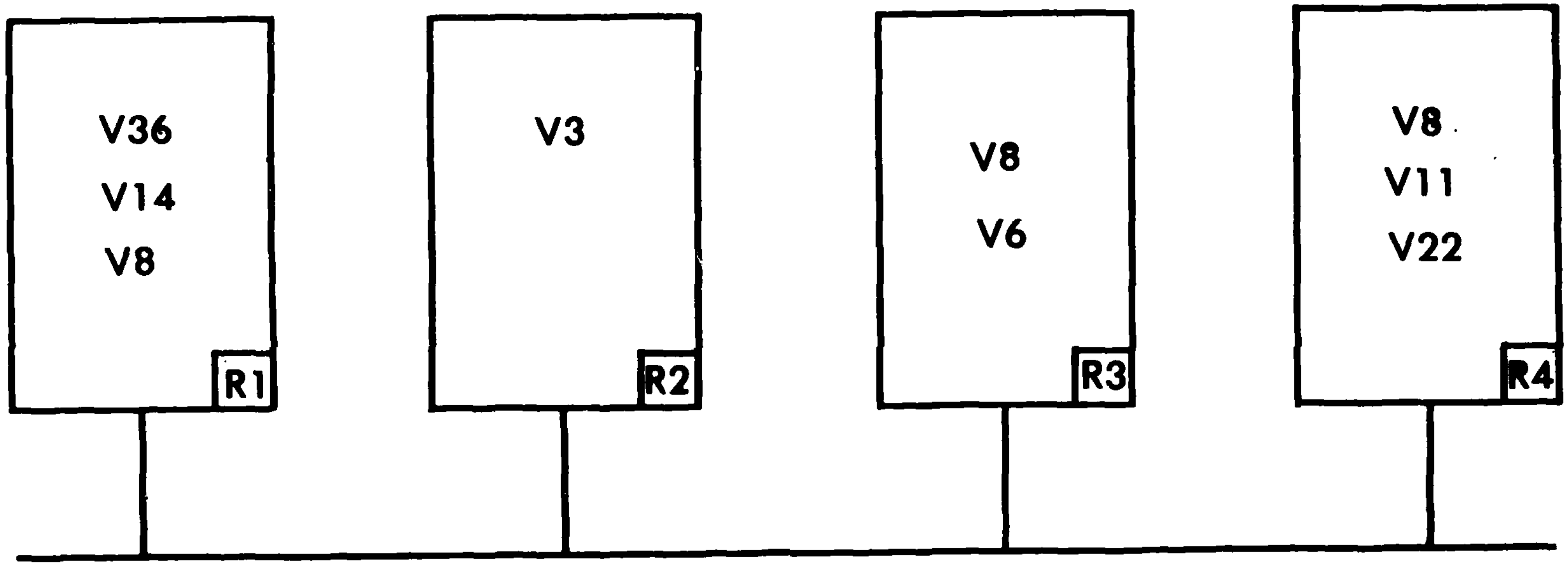
MULTICAST
(ONE TO SEVERAL)

LAZY SUSAN
(SEQUENTIAL ROUTING)



1268 07 APR 1982

FI LAN VIRTUAL ADDRESSING



- REAL ADDRESSES (R)
- VIRTUAL ADDRESSES (V)
- MULTIPLE VIRTUAL ADDRESSES (PER HOST, SHARED)

FILAN ERROR CONTROL

- MESSAGE SEQUENCE NUMBER
- ELAPSED TIME CHECKS
- SENDER RECEIVER AUTHORIZATION CHECK
- MESSAGE TYPE CHECK
- ON-LINE TESTING
- HEADER PROTECTION

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FI INTERFACES & INTEROPERABILITY

RATE INDEPENDENCE
INTERFACE CONVERSION
MESSAGE BUFFERING
VARIABLE LENGTH MESSAGES
VENDOR INDEPENDENCE
PROGRAMMABLE INTERFACE CONVERTERS
STANDARD FILAN INTERFACE

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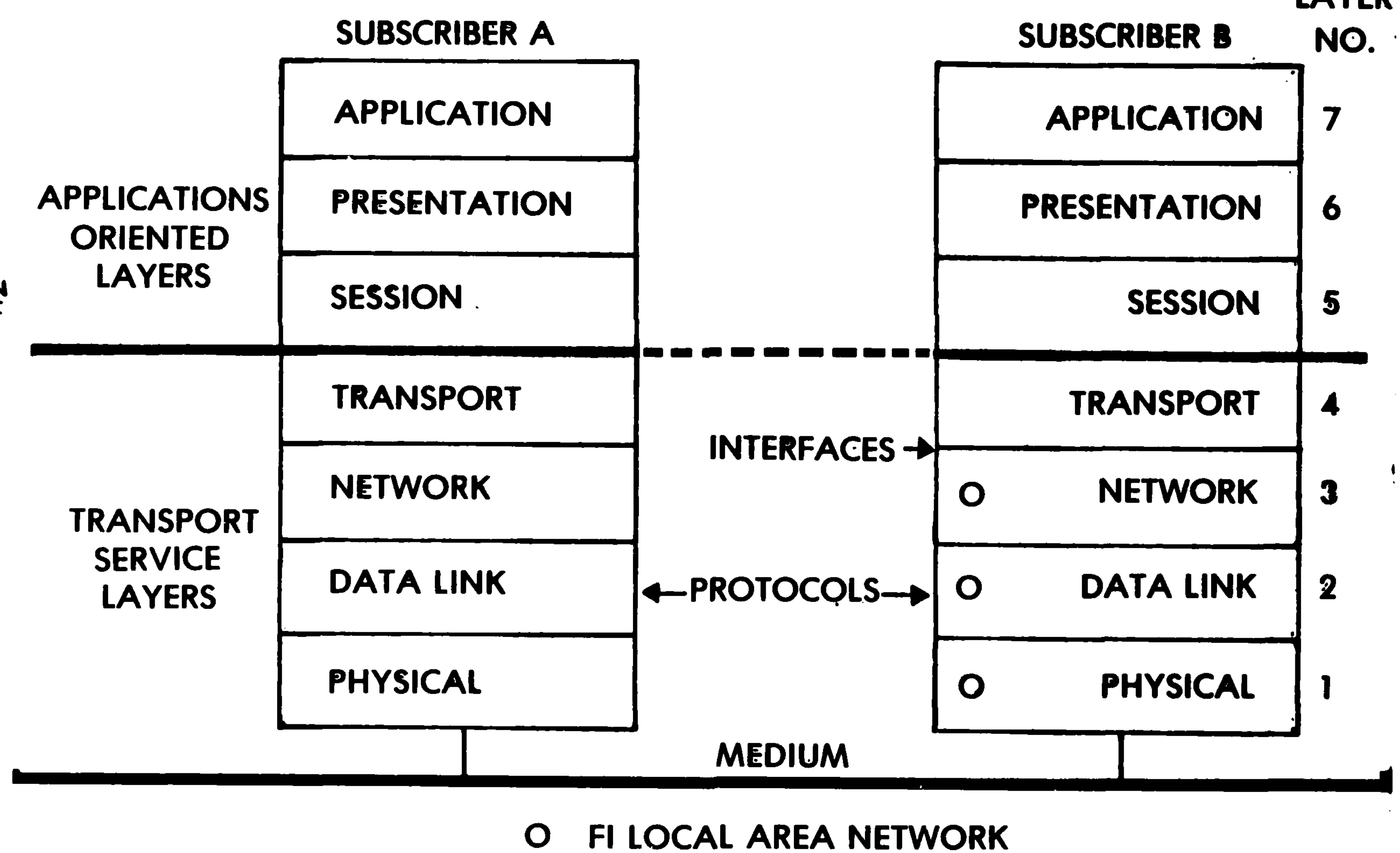
ISO REFERENCE MODEL FOR OPEN SYSTEMS INTERCONNECTION



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OPEN SYSTEMS INTERCONNECTION

	LAYER	PURPOSE
7	APPLICATION	END USER SETS TRANSFER CONDITIONS
6	PRESENTATION	CODE, LANGUAGE, FORMAT TRANSLATIONS
5	SESSION	NETWORK TO NETWORK EXCHANGE
4	TRANSPORT	TRANSMISSION CONTROL
3	*NETWORK	MESSAGE ROUTING & DELIVERY
2	*LINK	PACKET ASSEMBLY, ERROR CONTROL
1	*PHYSICAL	ELECTRICAL, MECHANICAL CONNECTION

*FI LOCAL AREA NETWORK

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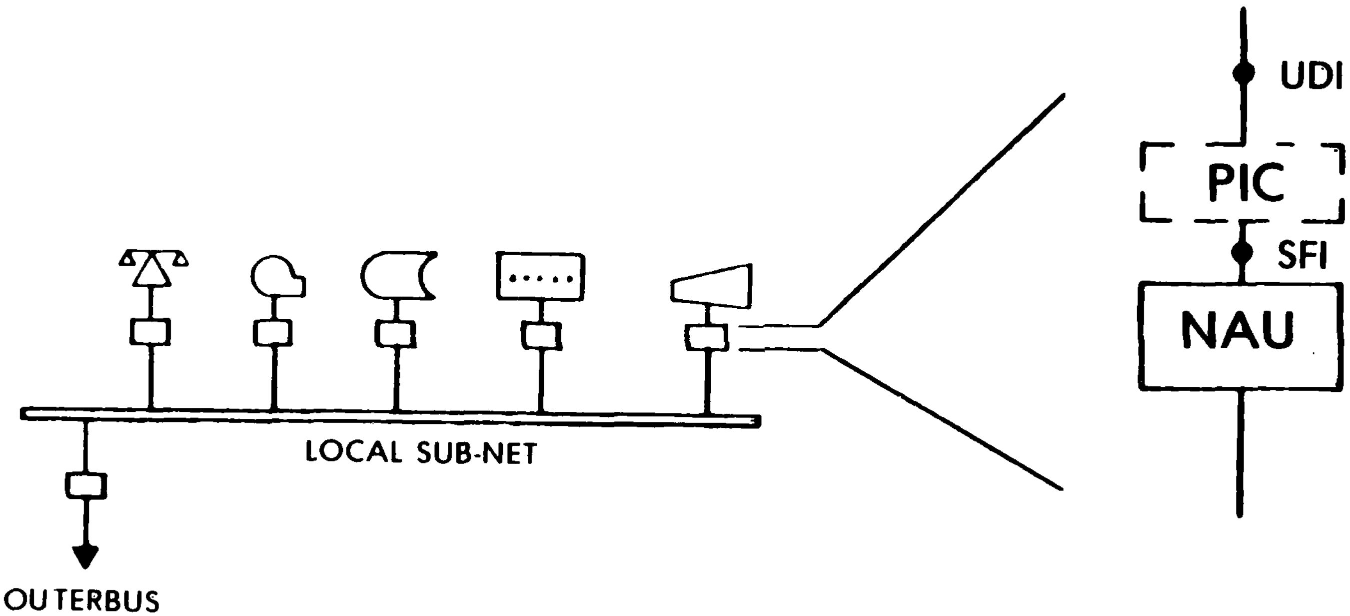
USER INTERFACE



UDI - USER DEFINED INTERFACE
PIC - PROGRAMMABLE INTERFACE CONVERTER
SFI - STANDARD FI INTERFACE (MIL-STD-FI)
NAU - NETWORK ACCESS UNIT

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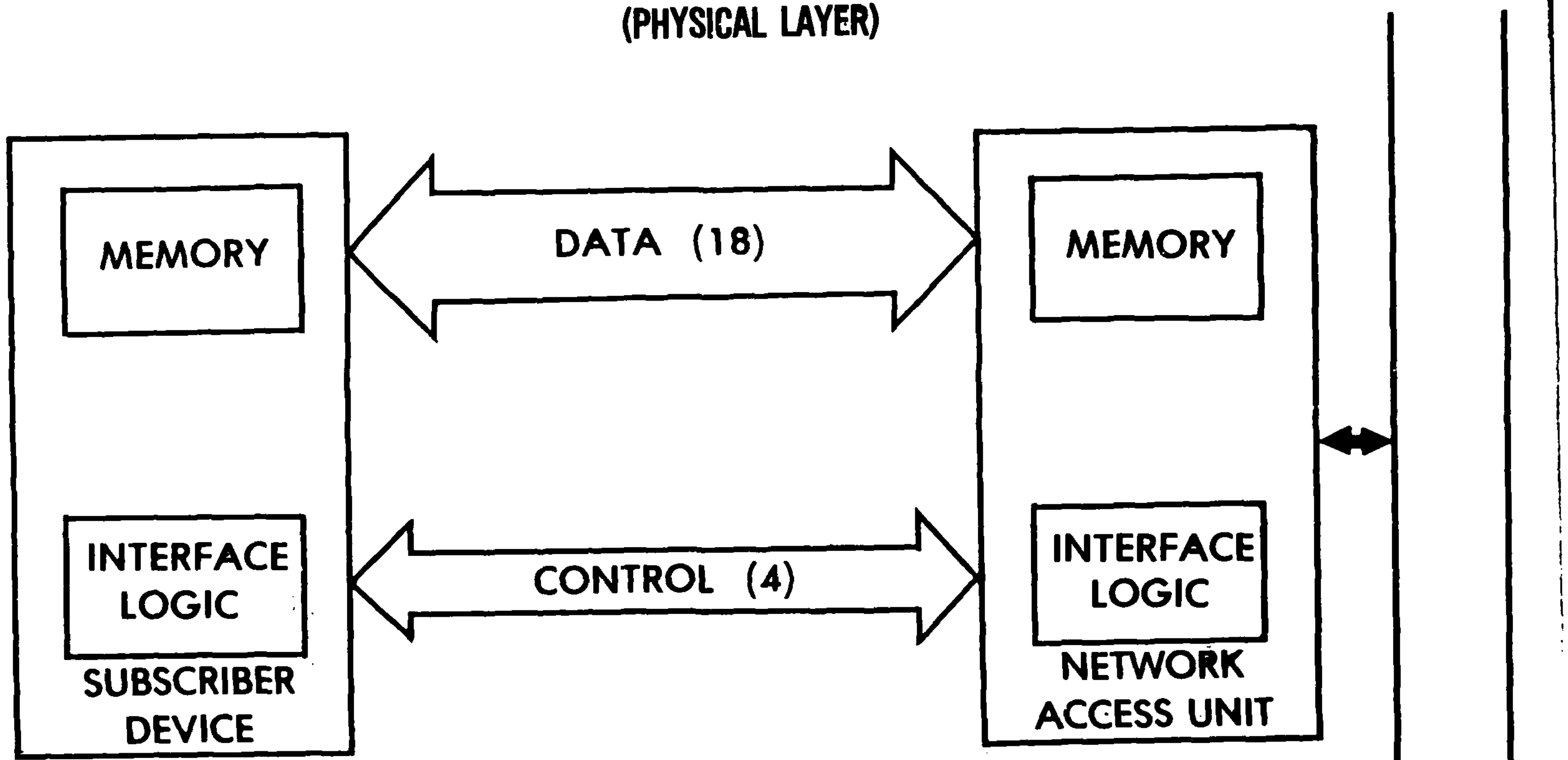
STANDARD FI INTERFACE
(PHYSICAL LAYER)



- FULLY ASYNCHRONOUS (UP TO 180 MBPS)
- VARIABLE BLOCK SIZE
- SIMPLE, STRAIGHTFORWARD LOGIC
- SYMMETRICAL DESIGN

FI STANDARD LINK LEVEL PROTOCOL

MSG TYPE	ACK/NAK	MODE
PRIORITY	SUBBUS ADDRESS	
DESTINATION VIRTUAL ADDRESS		
SOURCE VIRTUAL ADDRESS		
DESTINATION REAL ADDRESS		
SOURCE REAL ADDRESS		
WORD AND BIT COUNT		
MESSAGE NUMBER		
SUBBUS SEQUENCE NUMBER		
TRANSMIT TIME		
ERROR DETECTION		
DATA		

FI PROTOCOLS (BASED ON ISO MODEL)

NETWORK	NETWORK MANAGEMENT PERFORMANCE MONITORING TEST & DIAGNOSTICS
LINK	HEADER DEFINITION MESSAGE FRAMING ERROR CONTROL
PHYSICAL	MINITURE COAX FIBER OPTICS

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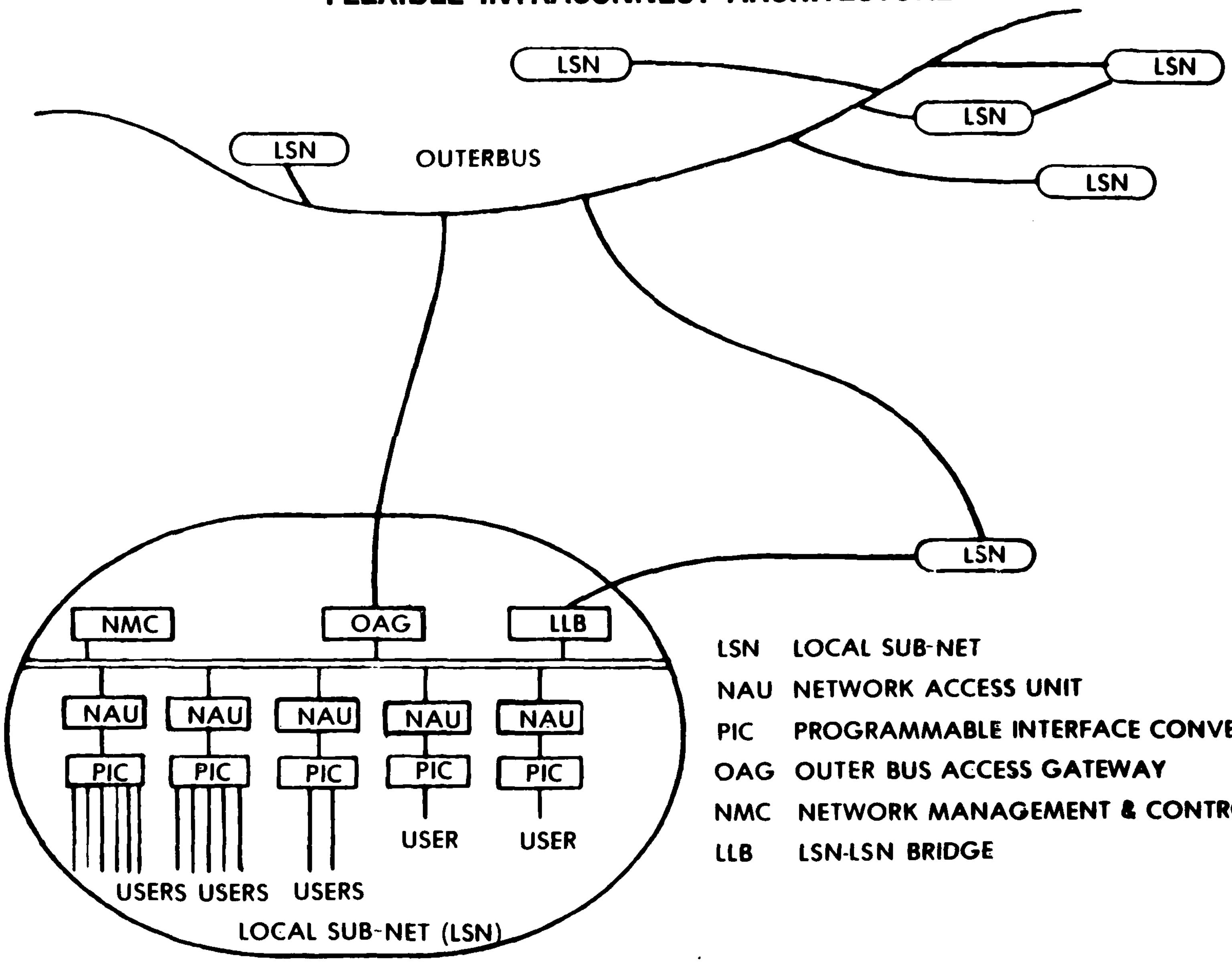
DESIGN CHARACTERISTICS

• TOPOLOGY:	BUS (LOCAL SUBNET), STAR (OUTERBUS)
• PROTOCOL:	DETERMINISTIC-SMART POLLING WITH REDUNDANT POLLERS
• MEDIA:	MINITURE COAX (LSN) COAX OR FIBER OPTICS (OUTERBUS)
• ERROR RATES:	DATA 10^{-12}, HEADERS 10^{-15}

• SUPPORTABLE STANDARD HARDWARE & SOFTWARE

FLEXIBLE INTRACONNECT ARCHITECTURE



LSN LOCAL SUB-NET
NAU NETWORK ACCESS UNIT
PIC PROGRAMMABLE INTERFACE CONVERTER
OAG OUTER BUS ACCESS GATEWAY
NMC NETWORK MANAGEMENT & CONTROL
LLB LSN-LSN BRIDGE

06 APR 1982 12&8

FLEXIBLE INTRACONNECT
DESIGN STANDARDS

PROTOCOLS	MIL-STD-(FI) ; PROGRAMMABLE INTERFACE CONVERTERS
HARDWARE	QPL JANTX PARTS (MRAP/SRAP) MIL-M-38510/530-01 (8086 MICROPROCESSOR) MIL-STD-454F (EQUIPMENT REQUIREMENTS)
SOFTWARE	MIL-STD-1753 FORTRAN MIL-STD-1815 ADA
SOFTWARE DEV'T	UNIX/PWB VAX 11/780
DOCUMENTATION	DOD-STD-7935.1-S (SOFTWARE/CPCIs) MIL-STD-490 (SYSTEM/CI SPECS) MIL-STD-483 (CONFIG. MGT)
BITE/BITF	IEEE-STD-488
ARCHITECTURE	ISO OPEN SYSTEMS INTERCONNECTION

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FI OPERATING SYSTEM

- MANAGEMENT & CONTROL
- RESOURCE ALLOCATION
- ACCESS CONTROL
- CONFIGURATION MANAGEMENT
- TRAFFIC STATISTICS
- SERVICE AUTHORIZATIONS
- PROGRAM DOWNLOAD
- UNIVERSAL TEST & SERVICE PORTS

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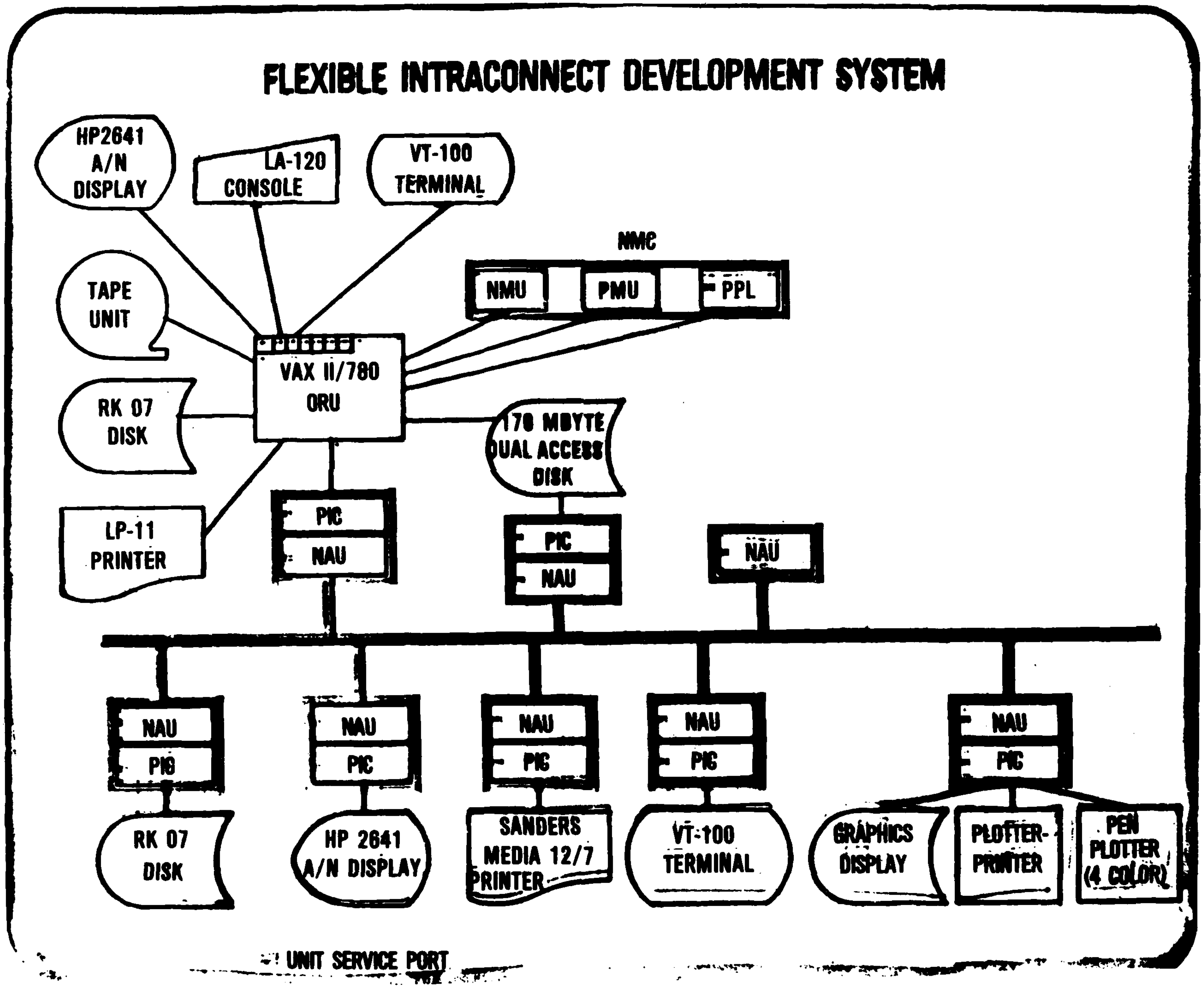
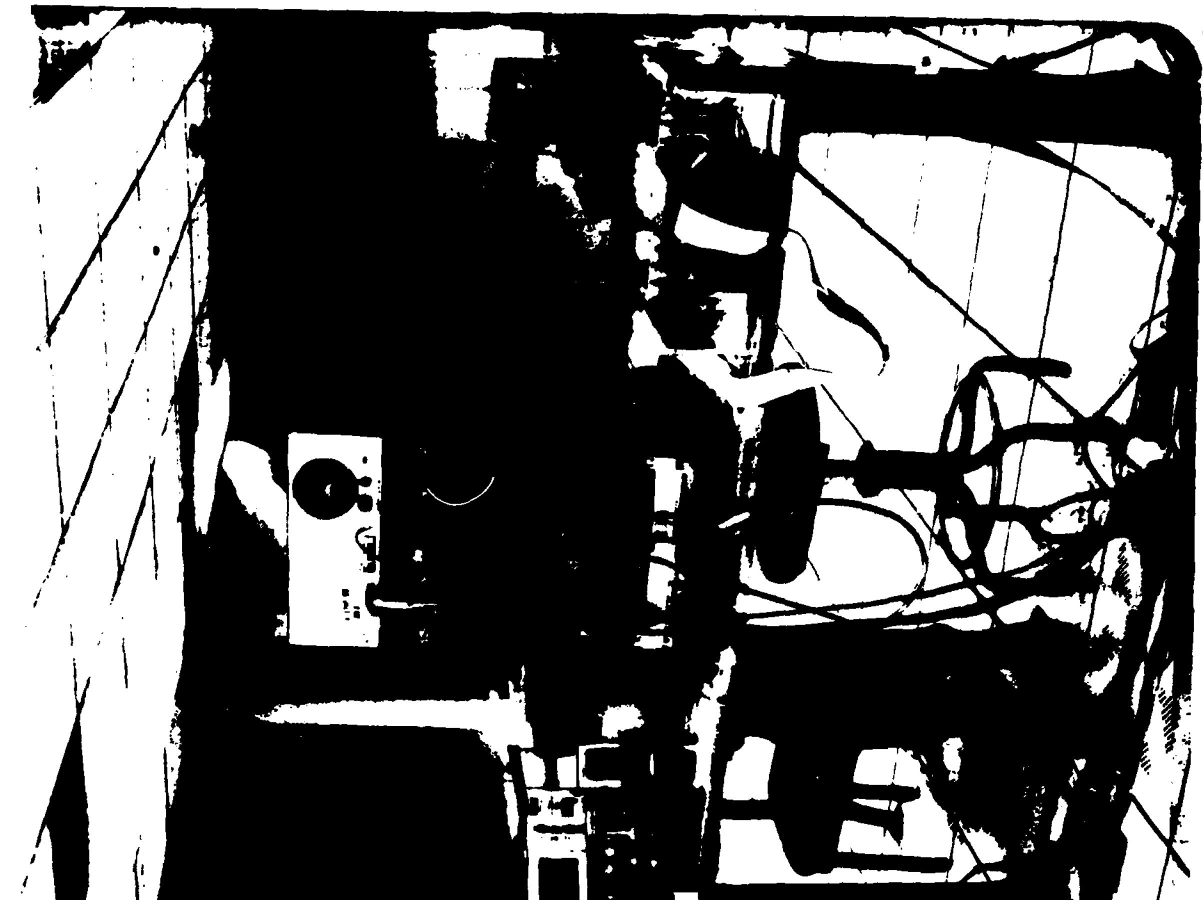
DEVELOPMENT PROGRAM OBJECTIVES

- PROVE ENGINEERING PERFORMANCE
- TEST/DEMONSTRATE CONCEPT
- PROVE/VERIFY STANDARDS
- TRANSFER TECHNOLOGY


FLEXIBLE INTRACONNECT DEVELOPMENT SYSTEM
HP2641 A/N DISPLAY
LA-120 CONSOLE
VT-100 TERMINAL
NMC
NMU
PMU
PPL
TAPE UNIT
VAX II/780 ORU
RK 07 DISK
170 MBYTE DUAL ACCESS DISK
LP-11 PRINTER
PIC
NAU
PIC
NAU
NAU
NAU
PIG
RK 07 DISK
NAU
PIC
HP 2641 A/N DISPLAY
NAU
PIC
SANDERS MEDIA 12/7 PRINTER
NAU
PIC
VT-100 TERMINAL
NAU
PIC
GRAPHICS DISPLAY
PLOTTER-PRINTER
PEN PLOTTER (4 COLOR)
UNIT SERVICE PORT



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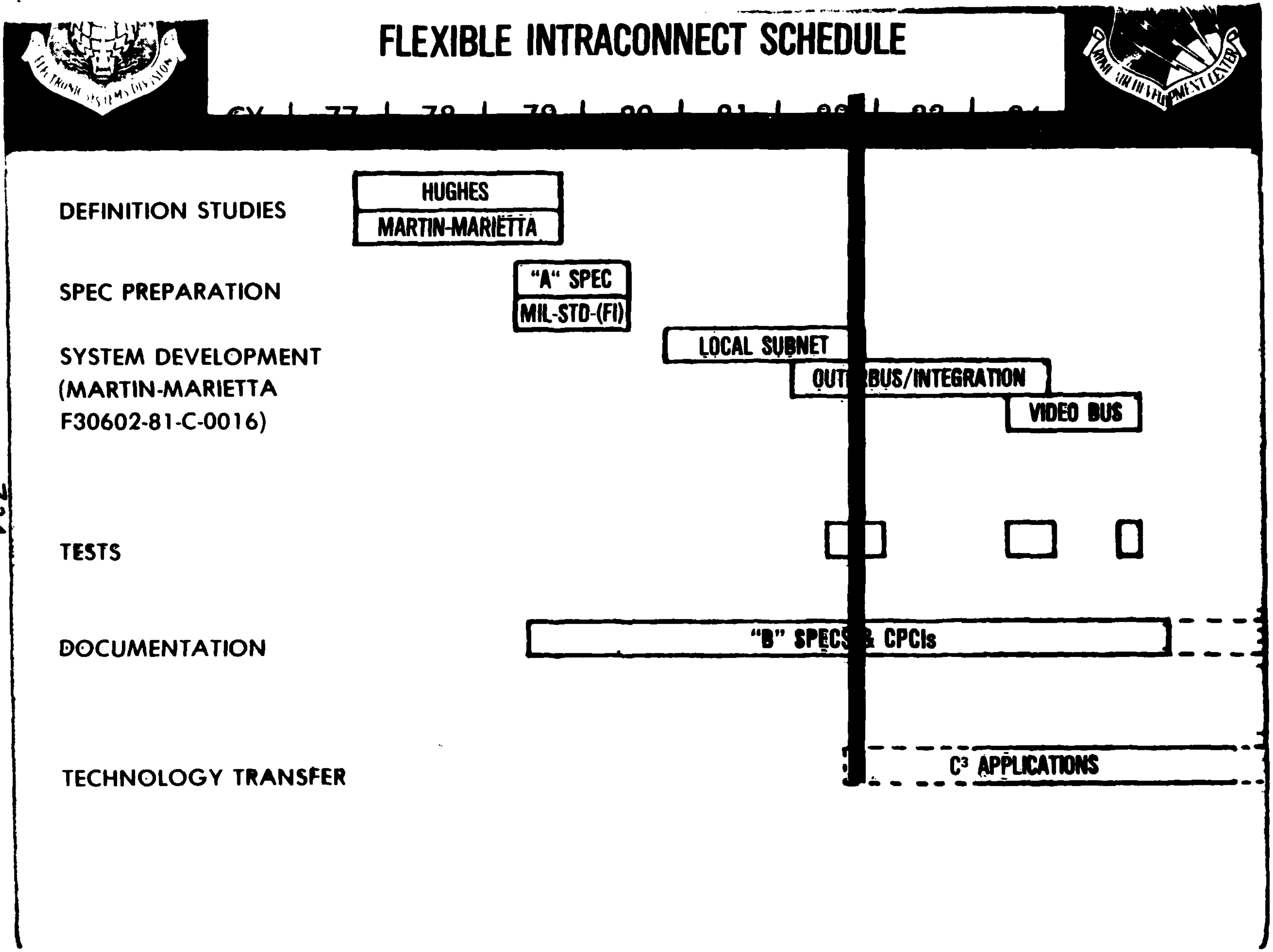
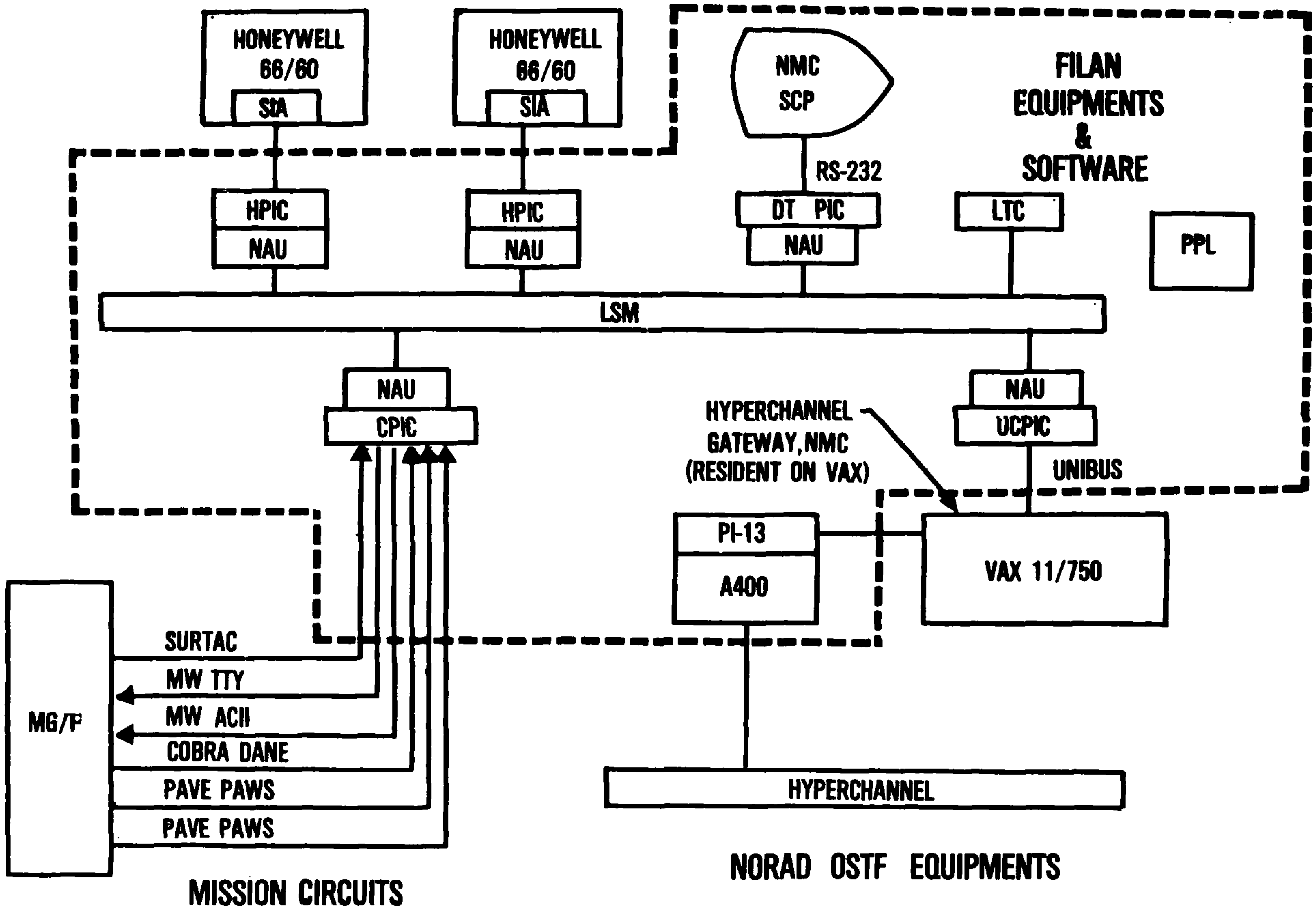
P.2


FLEXIBLE INTRACONNECT SCHEDULE
DEFINITION STUDIES
HUGHES
MARTIN-MARIETTA
SPEC PREPARATION
"A" SPEC
MIL-STD-(FI)
SYSTEM DEVELOPMENT
(MARTIN-MARIETTA
F30602-81-C-0016)
LOCAL SUBNET
OUT BUS/INTEGRATION
VIDEO BUS
TESTS
DOCUMENTATION
"B" SPECS & CPCIs
TECHNOLOGY TRANSFER
C^3 APPLICATIONS

NORAD OFF SITE TEST FACILITY
LOCAL AREA NETWORK DEMONSTRATION



A LOCAL AREA NETWORK FOR COMMAND CENTERS

Litton AMECOM

AGENDA

- UBITS/LAN
- REQUIREMENTS
- SYSTEM ARCHITECTURE
- ADVANTAGES AND CAPABILITIES
- ENHANCEMENTS PLANNED

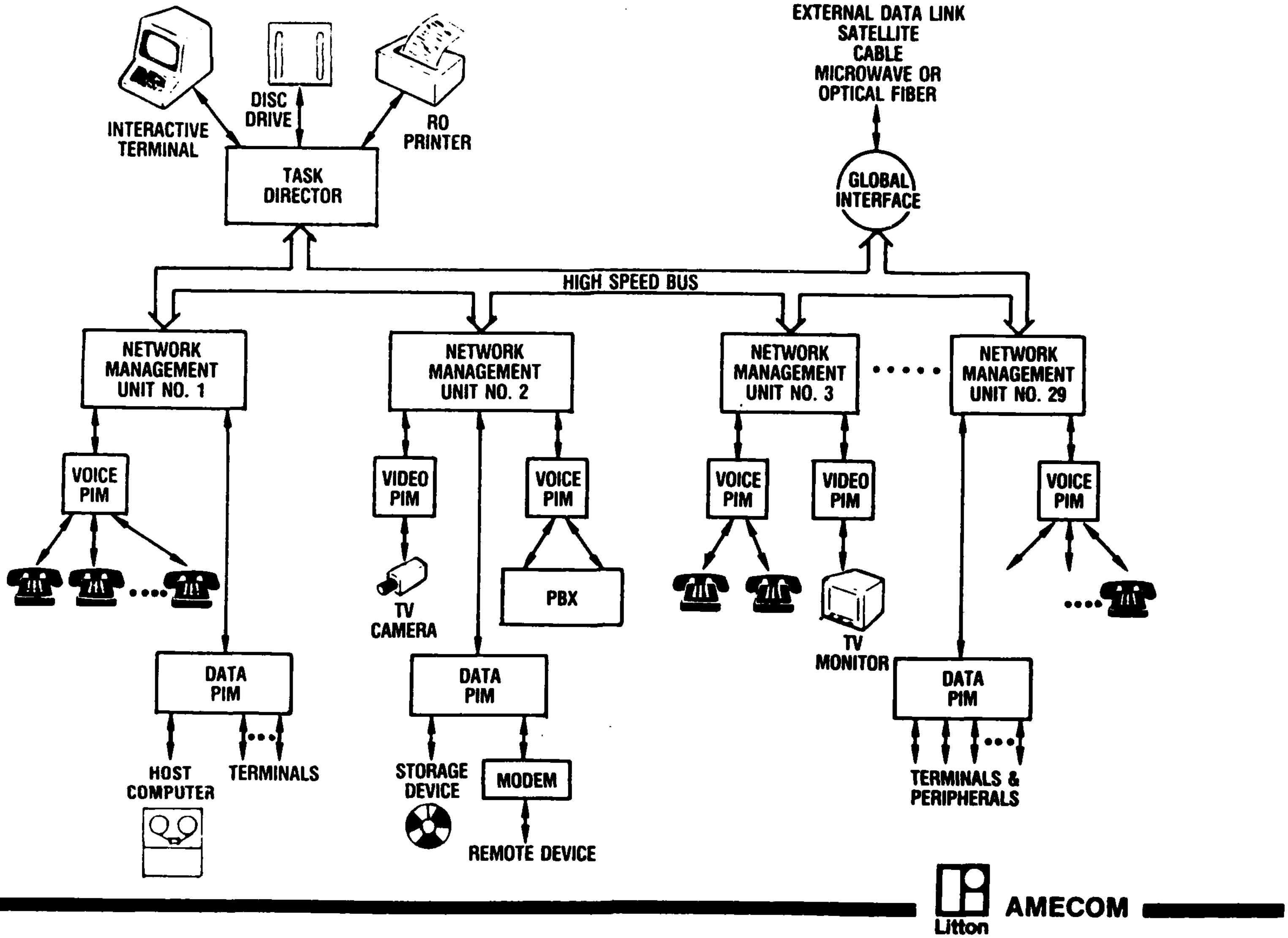
Litton AMECOM

UBITS SYSTEM REQUIREMENTS

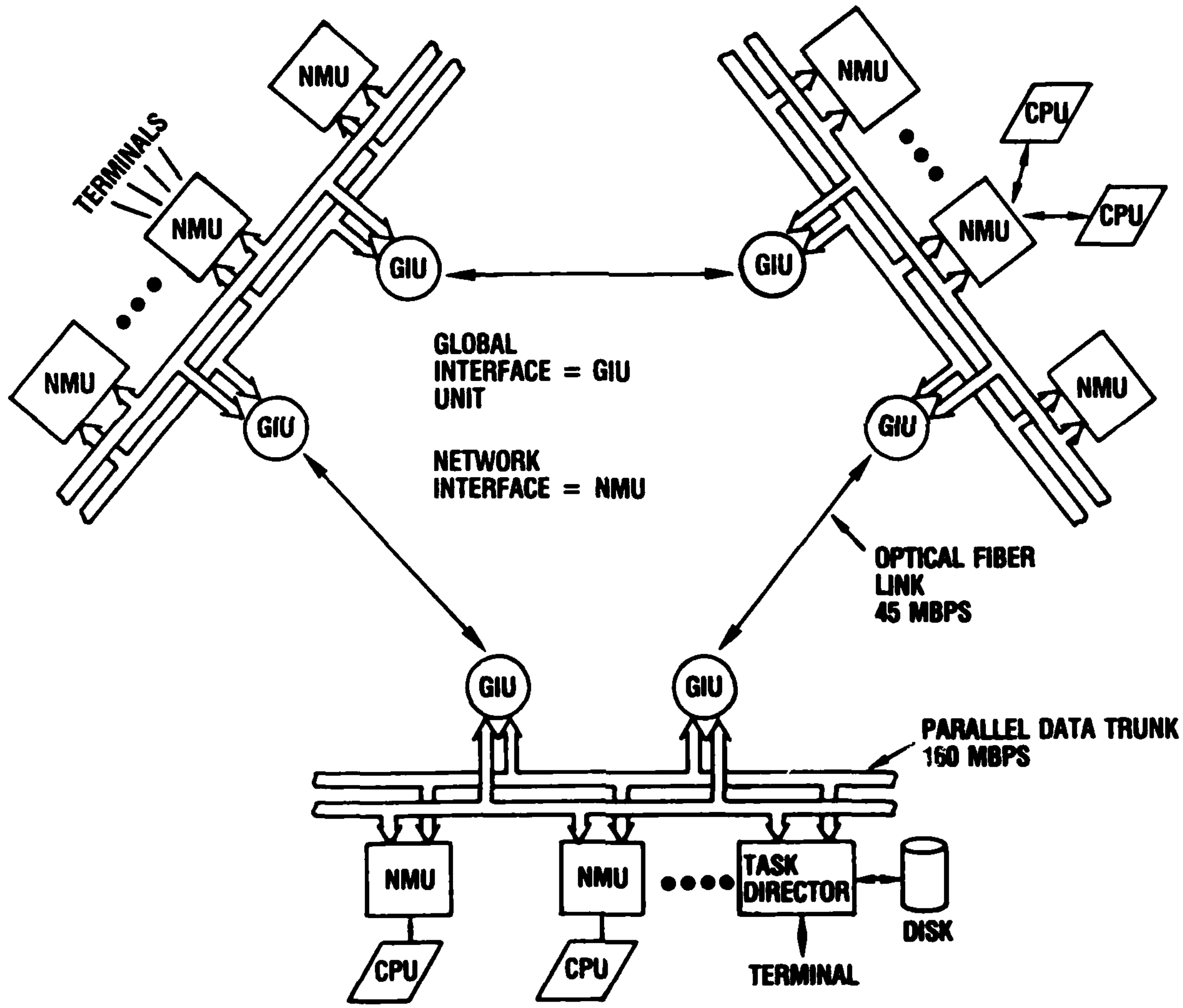
- RAPID INTERCONNECT AND CONTROL OF DATA DEVICES
- AUTOMATED MESSAGE PREPROCESSING
- COMMUNICATIONS CONTROL TERMINAL
- INTEGRATED SERVICE FOR DATA, VOICE AND VIDEO
- SYSTEM CAPABILITY EXPANSION
- SYSTEM MODULARITY

Litton AMECOM

LOCAL BUS BLOCK DIAGRAM

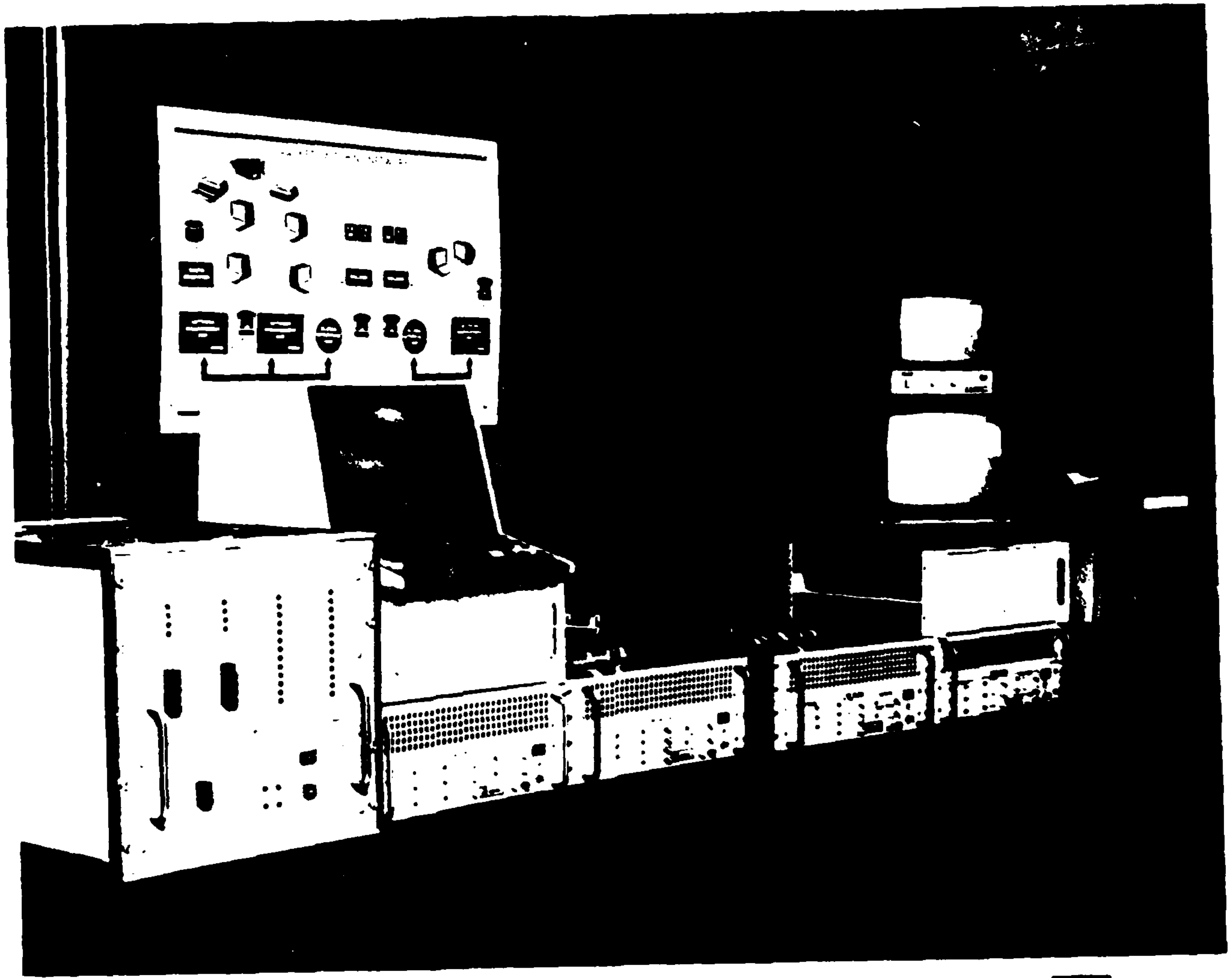


UBITS NETWORK EXAMPLE



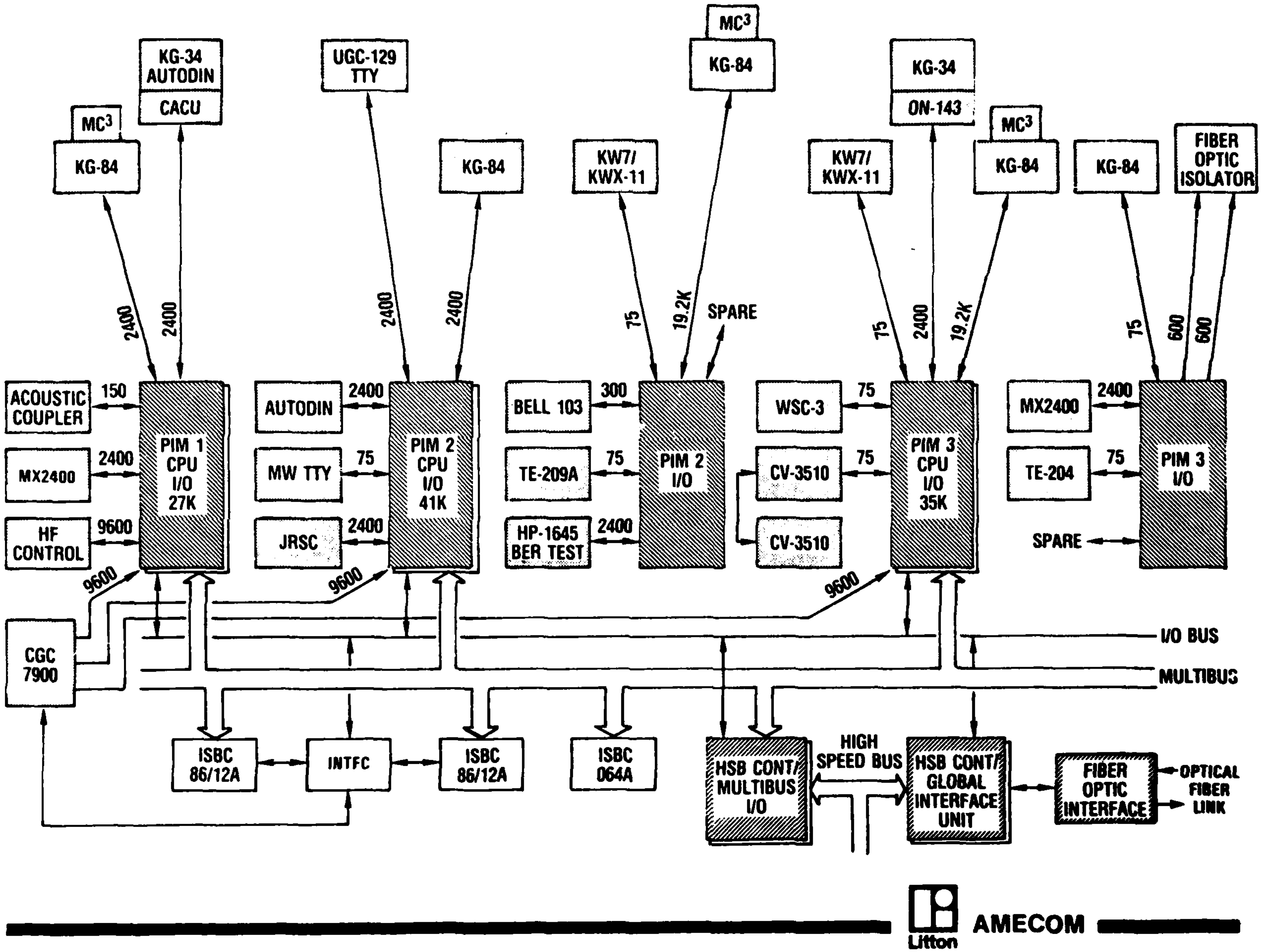
Litton AMECOM

UBITS DEVELOPMENT SYSTEM

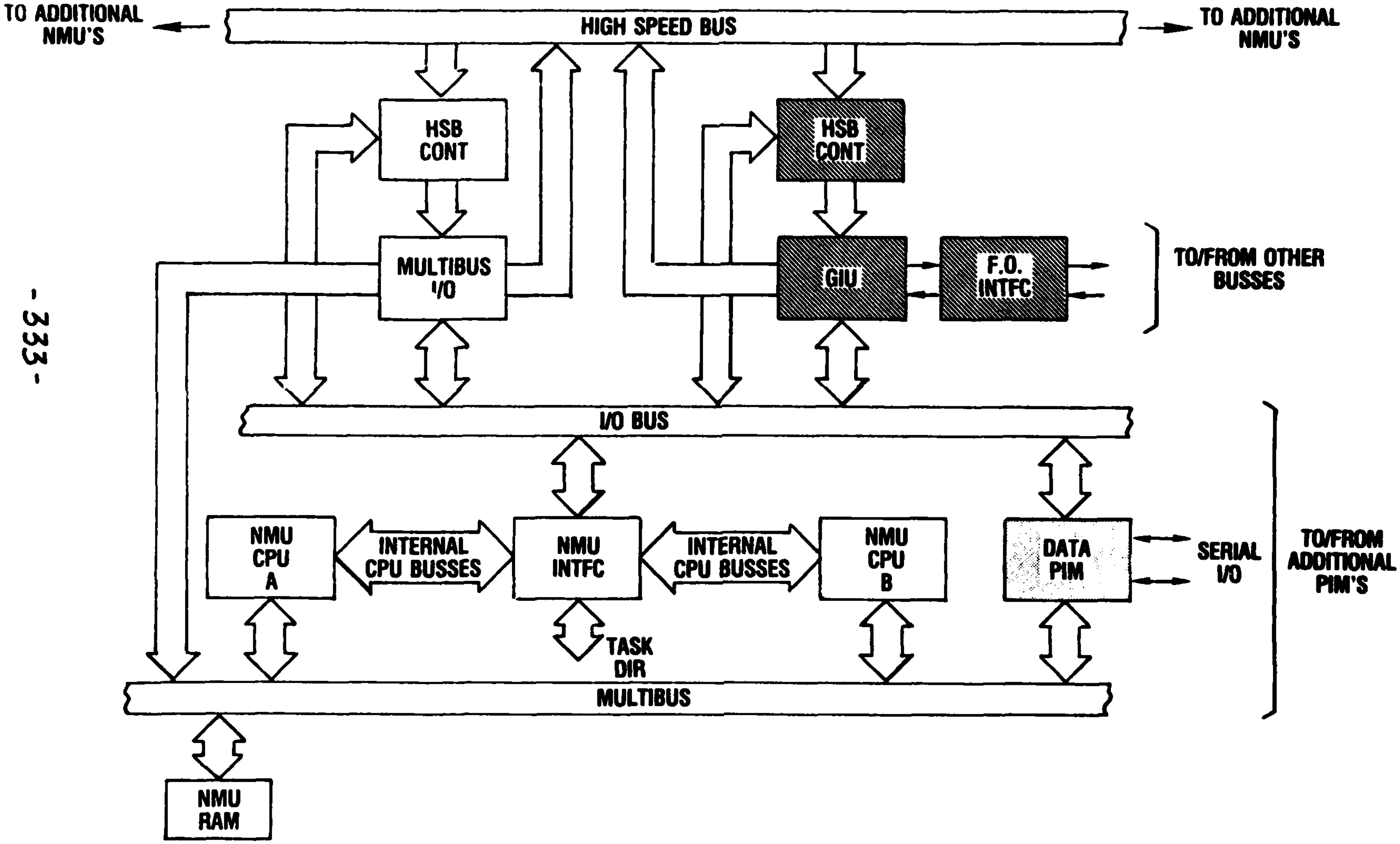


Litton AMECOM

NMU APPLICATION

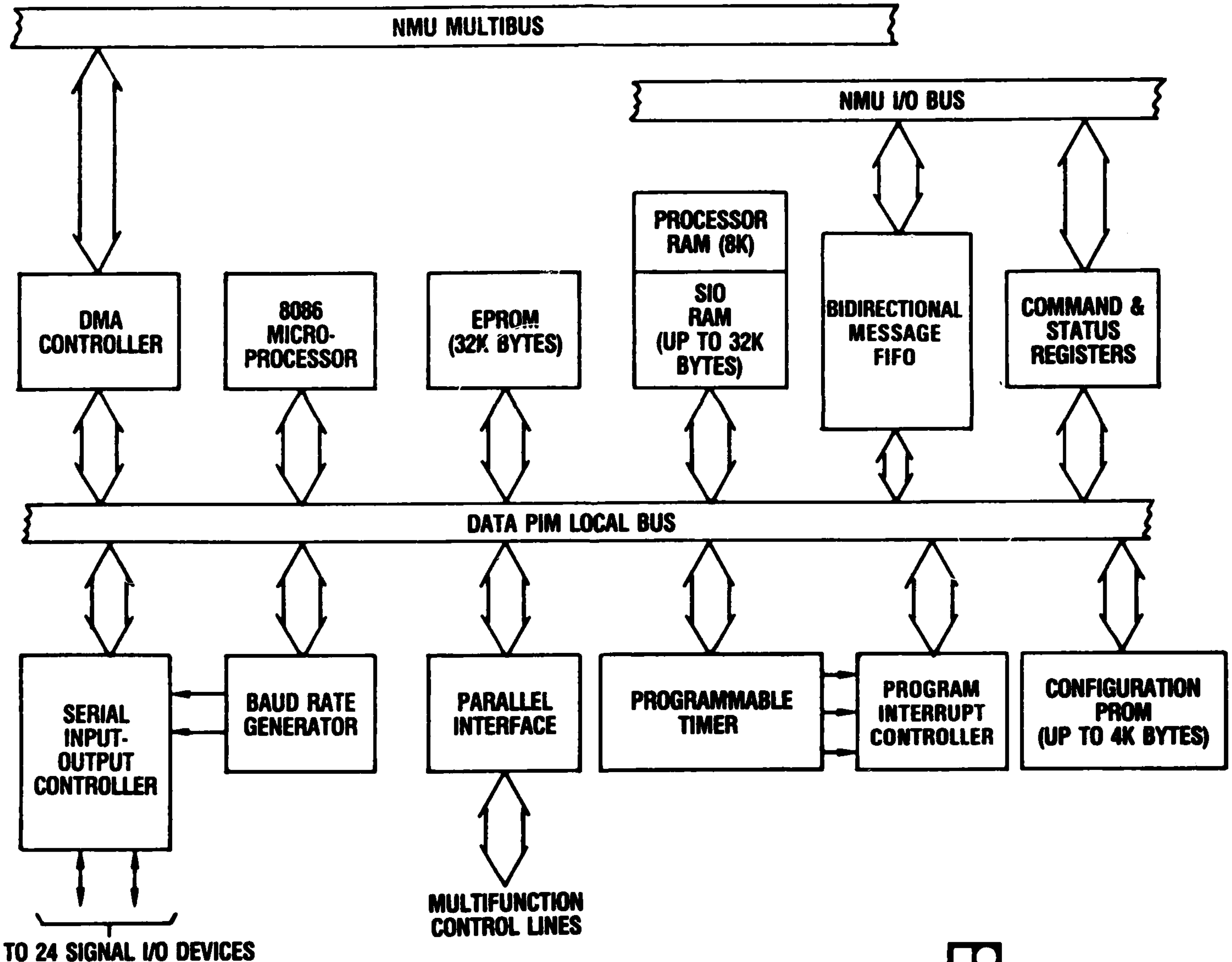


NMU CONFIGURATION BLOCK DIAGRAM



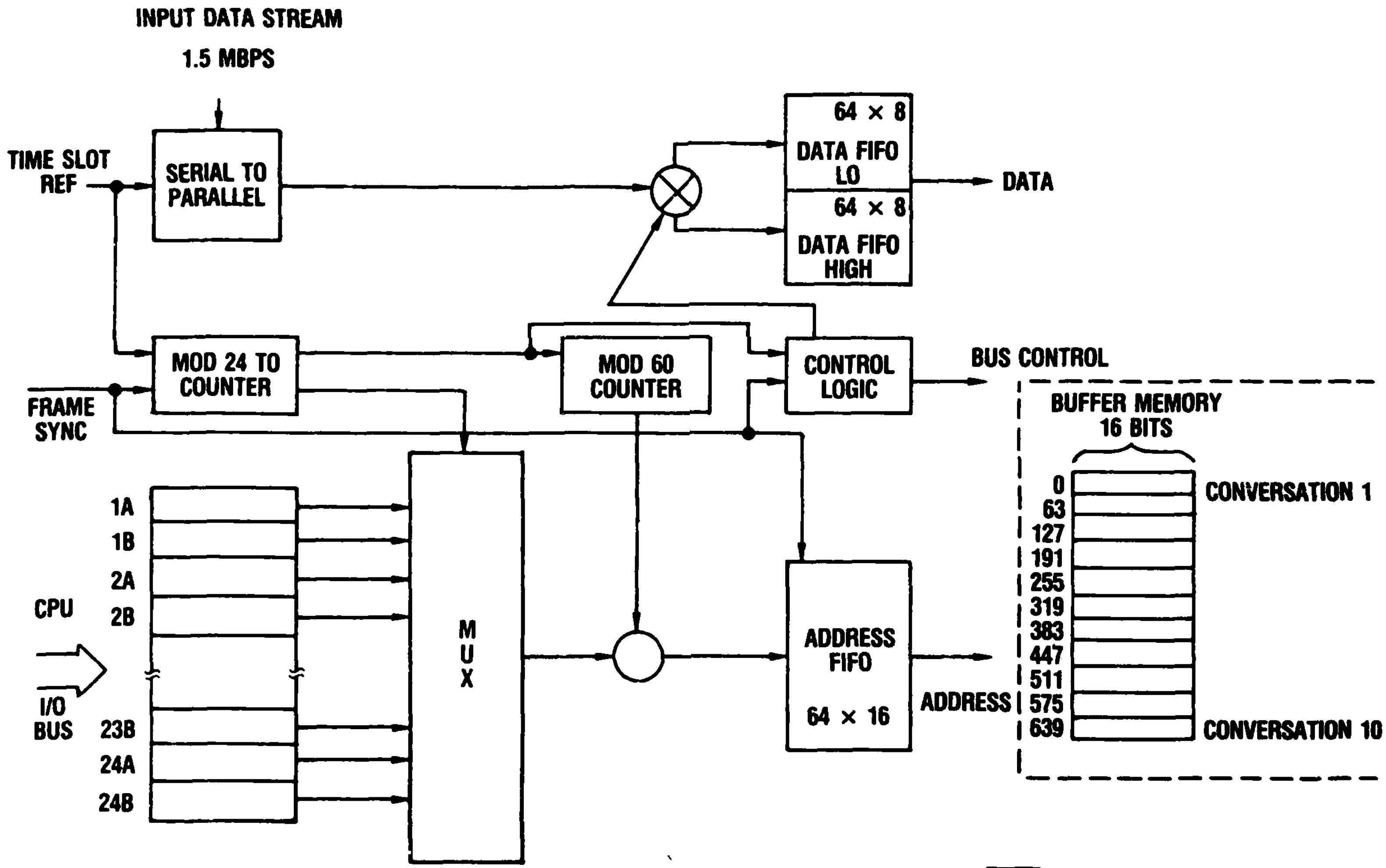
Litton AMECOM

SERIAL DATA PIM BLOCK DIAGRAM



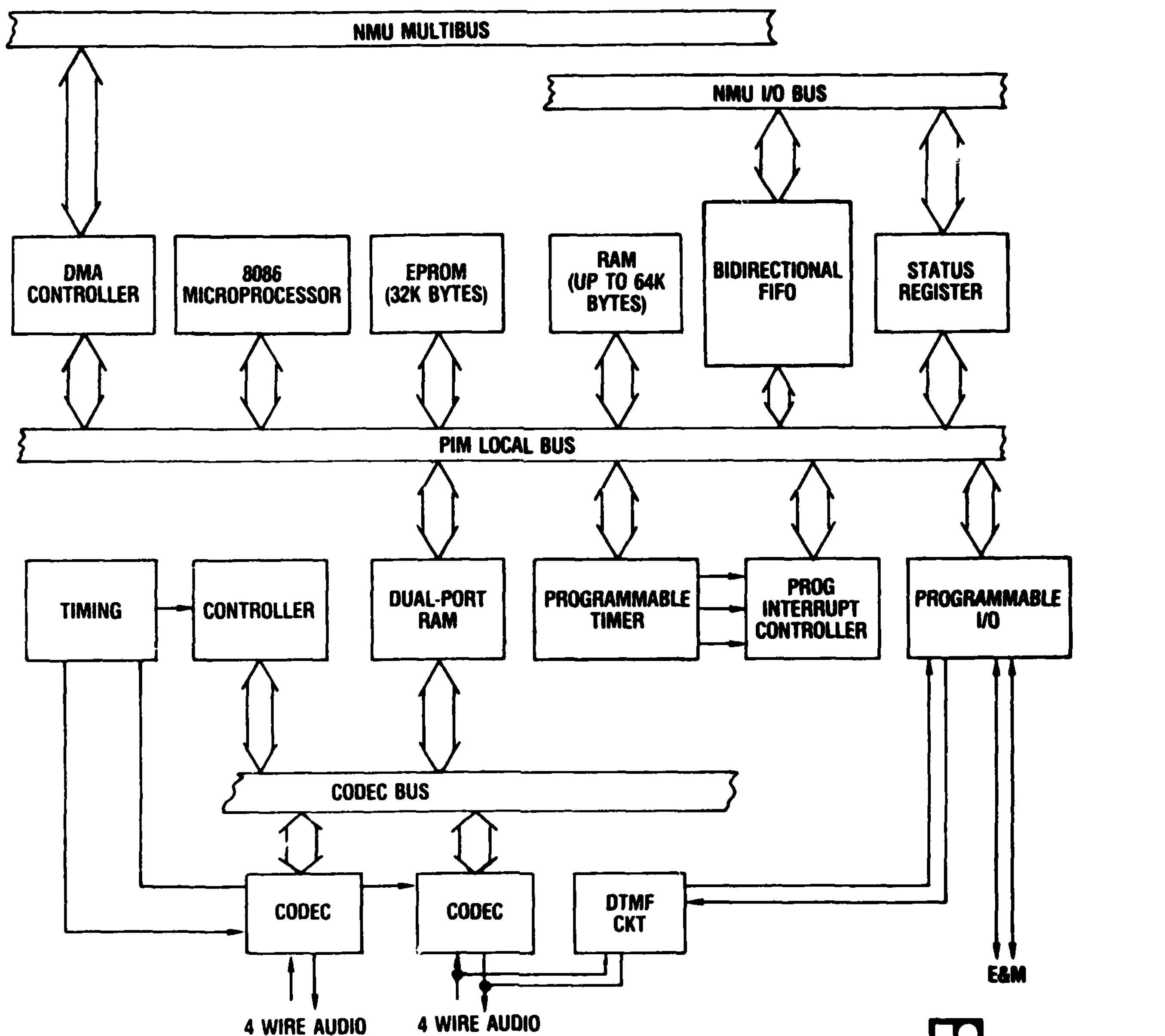
Litton AMECOM

T1 CARRIER PIM



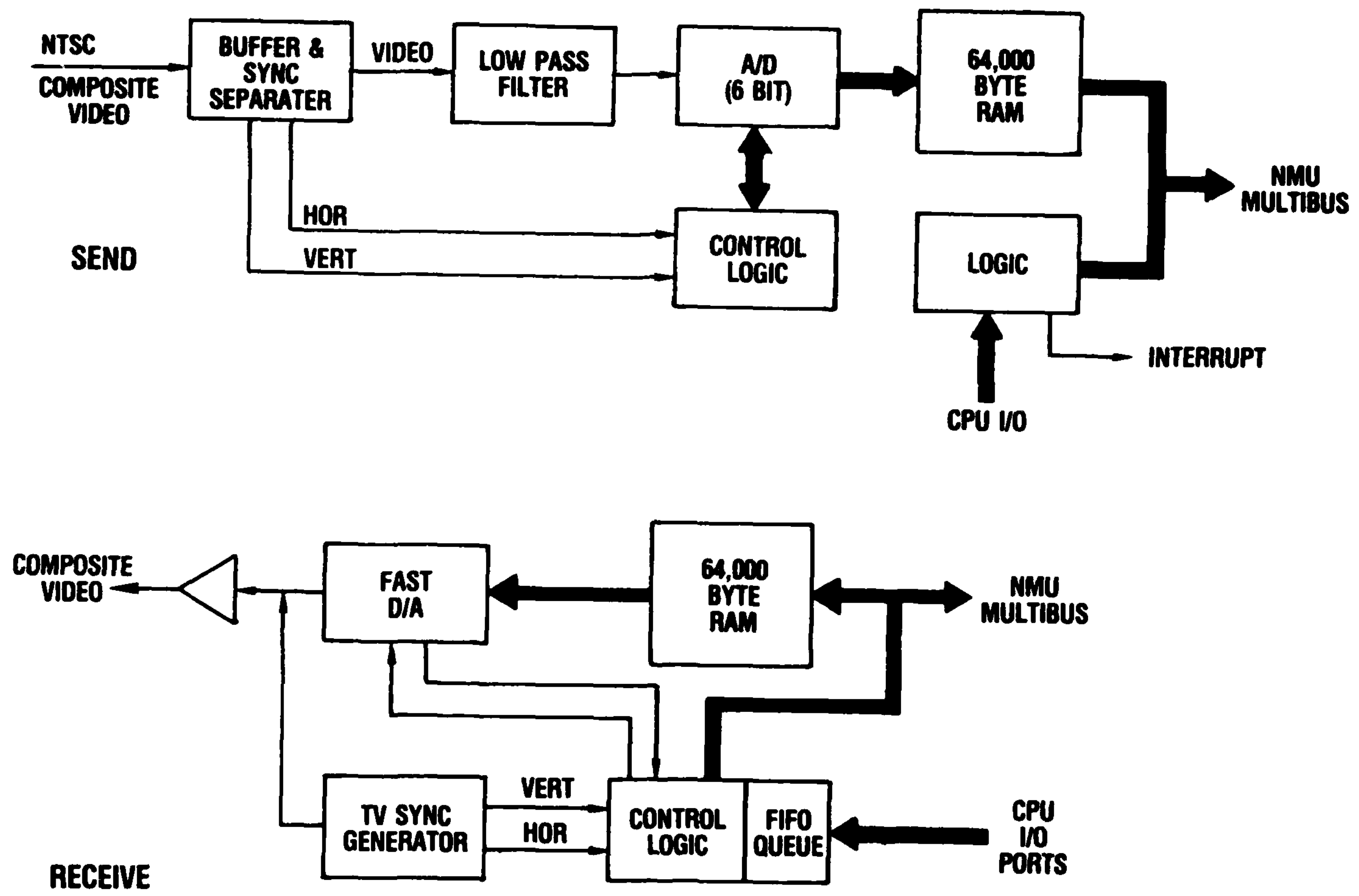
Litton AMECOM

VOICE PIM BLOCK DIAGRAM



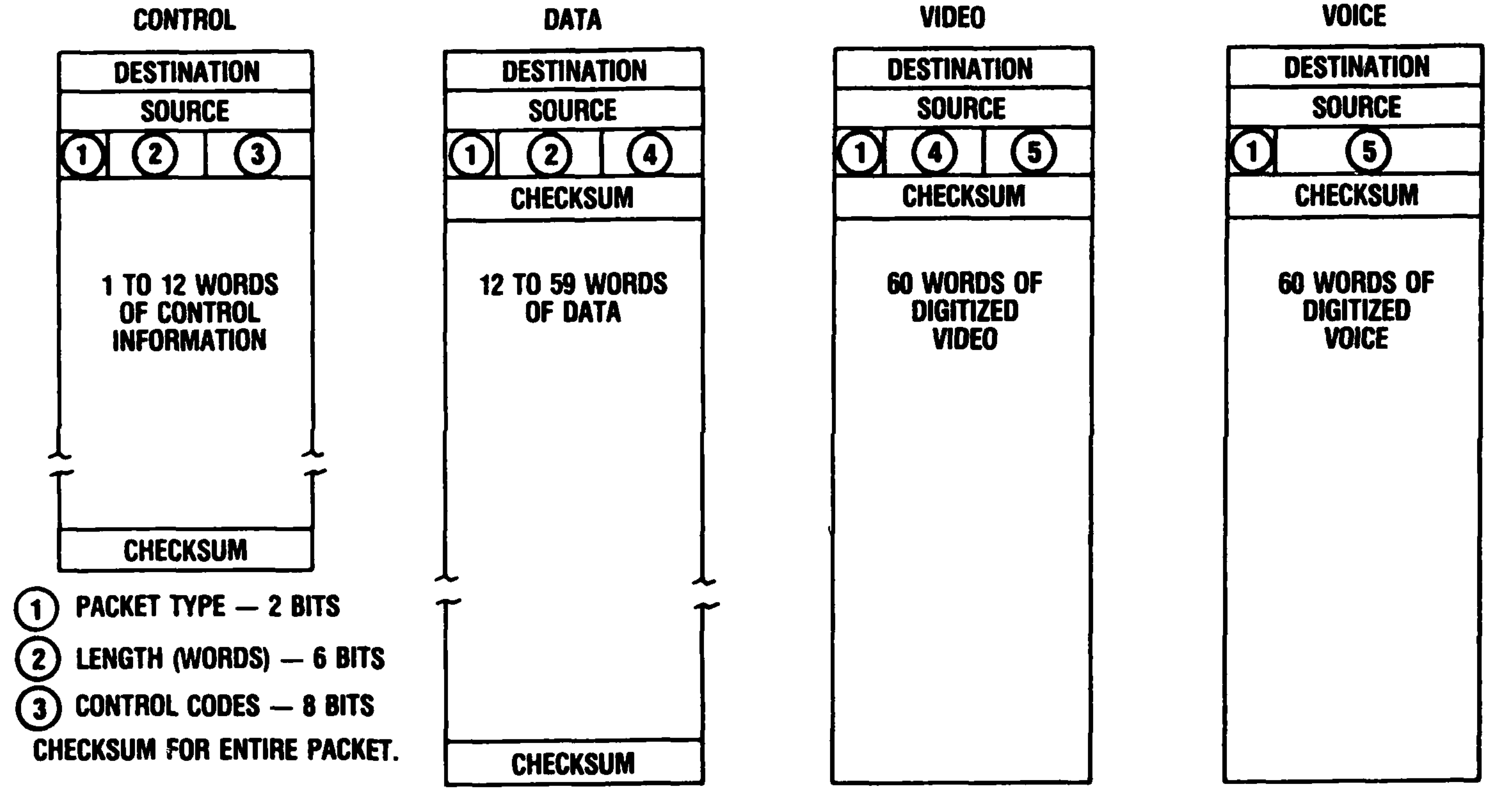
Litton AMECOM

VIDEO PIM BLOCK DIAGRAM



Litton AMECOM

PACKET FORMAT



CONTROL

1. PACKET TYPE — 2 BITS
2. LENGTH (WORDS) — 6 BITS
3. CONTROL CODES — 8 BITS

CHECKSUM FOR ENTIRE PACKET.

DATA

1. PACKET TYPE — 2 BITS
2. LENGTH (BYTES) — 7 BITS
4. SEQUENCE NO. — 7 BITS

VIDEO

1. PACKET TYPE — 2 BITS
4. SEQUENCE NO. — 7 BITS
5. UNUSED — 7 BITS

CHECKSUM FOR HEADER ONLY.

VOICE

1. PACKET TYPE — 2 BITS
5. UNUSED — 14 BITS

CHECKSUM FOR HEADER ONLY.

SEPARATE CHECKSUM FOR HEADER AND DATA.

Litton AMECOM

TASK DIRECTOR FUNCTIONS

- INITIALIZATION
- RECONFIGURATIONS
- CALL CONTROL
- AUTOMATIC FAULT REPORTING/DIAGNOSTICS
- FAULT ISOLATION DIAGNOSTICS

Litton AMECOM

ADVANTAGES OF UBITS LAN

- REAL TIME COMMUNICATIONS
- PROVIDES AUTOMATED CONTROL OF DEVICE CONNECTIVITY
- MATCHES ELECTRICAL INTERFACES OF DISIMILAR DEVICES
- PROVIDES CAPABILITY FOR SPEED CODE & PROTOCOL CONVERSION
- PROVIDES STATUS MONITORING AND REPORTING
- RECONFIGURABLE CLASSMARKING
- RECONFIGURATION TO SELECTED COMM. PLANS
- RELIABLE OPERATION THROUGH DISTRIBUTED CONTROL AND REDUNDANCY

Litton AMECOM

SUMMARY OF CAPABILITIES

SYSTEM COMPONENTS	CHARACTERISTICS	FUNCTION	PERFORMANCE	APPLICATION
GLOBAL INTERFACE UNIT (GIU)	HARDWIRED DESIGN.	HIGH SPEED SERIAL	45 MBPS OPERATION.	POINT TO POINT LINKS FOR PRIVATE NETWORKS
NETWORK MANAGEMENT UNIT (NMU)	16 BIT MICROPROCESOR CONTROLLED (REDUNDANT) MULTIMASTER BUS ARCHITECTURE.	HIGH SPEED PARALLEL INTERFACE CONTENTION, ERROR, AND FLOW CONTROL	160 MBPS PARALLEL INTERFACE. 10 MBPS THROUGHPUT.	REAL TIME, INTEGRATED VOICE, VIDEO, AND DATA COMMUNICATIONS SYSTEMS.
VOICE PIM(S)	HARDWIRED DESIGN. MULTIBUS COMPATIBLE.	T1 MUX/DEMUX	24 CHANNELS AT 64 KBPS. 1.5 MBPS THROUGHPUT	
	MICROPROCESSOR CONTROLLED. MULTIBUS COMPATIBLE.	SINGLE ANALOG VOICE CHANNEL	SINGLE CHANNEL AT 64KBPS	VOICE SWITCHING INTERFACES
VIDEO PIM	HARDWIRED DESIGN. MULTIBUS COMPATIBLE.	A/D, D/A CONVERSIONS. CCTV, CAMERA, TV MONITOR INTERFACES.	2 FRAMES/SEC. 1 MBPS THROUGHPUT.	VIDEO CONFERENCING. SECURITY SYSTEMS.
DATA PIM	16 BIT MICROPROCESSOR BASED. MULTIBUS COMPATIBLE. DMA CAPABILITY. SOFTWARE RECONFIGURABLE. OPTIONAL I/O PROCESSOR.	PACKET ASSEMBLY/ DISASSEMBLY (PAD). PIM TO PIM PROTOCOL. ASYNCHRONOUS AND SYNCHRONOUS LINK PROTOCOLS.	SINGLE PROCESSOR CONFIG. 220 KBPS MAX THROUGHPUT. FOR SINGLE DEVICE. UP TO 24 FULL DUPLEX 9600 BAUD PORTS.	TERMINAL HANDLER. ASYNCH/SYNCH PORT. PUBLIC NETWORK GATEWAY. PROTOCOL CONVERSION. DATA CONCENTRATION. STATISTICAL MULTIPLEXING.

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PLANNED ENHANCEMENTS

- FIBER OPTIC BUS
  - —STAR TOPOLGY
  - —LINEAR BUS
- MLS/LAN
  - —FORMAL MATHEMATICAL SECURITY MODEL
  - —OPERATIONAL COMMUNICATIONS REQUIREMENTS
  - —MLS/LAN ARCHITECTURE
  - —MLS/LAN DEVELOPMENT

Litton AMECOM

NAVAL COMMAND CENTERS NETWORK

AN APPLICATION OF THE INFORMATION SYSTEM PROTOTYPE TO NAVAL COMMAND CENTERS

NESEC-V
AUGUST 1982

NAVAL COMMAND AND CONTROL SYSTEM PROFILE

- 34 OPERATIONAL ASHORE NODES WITHIN NCCS

NCC	1
NOSIC	1
FCC	3
FOSIC	3
FOSIF	2
ATCC	3
AOCC	5
ASWOC	16

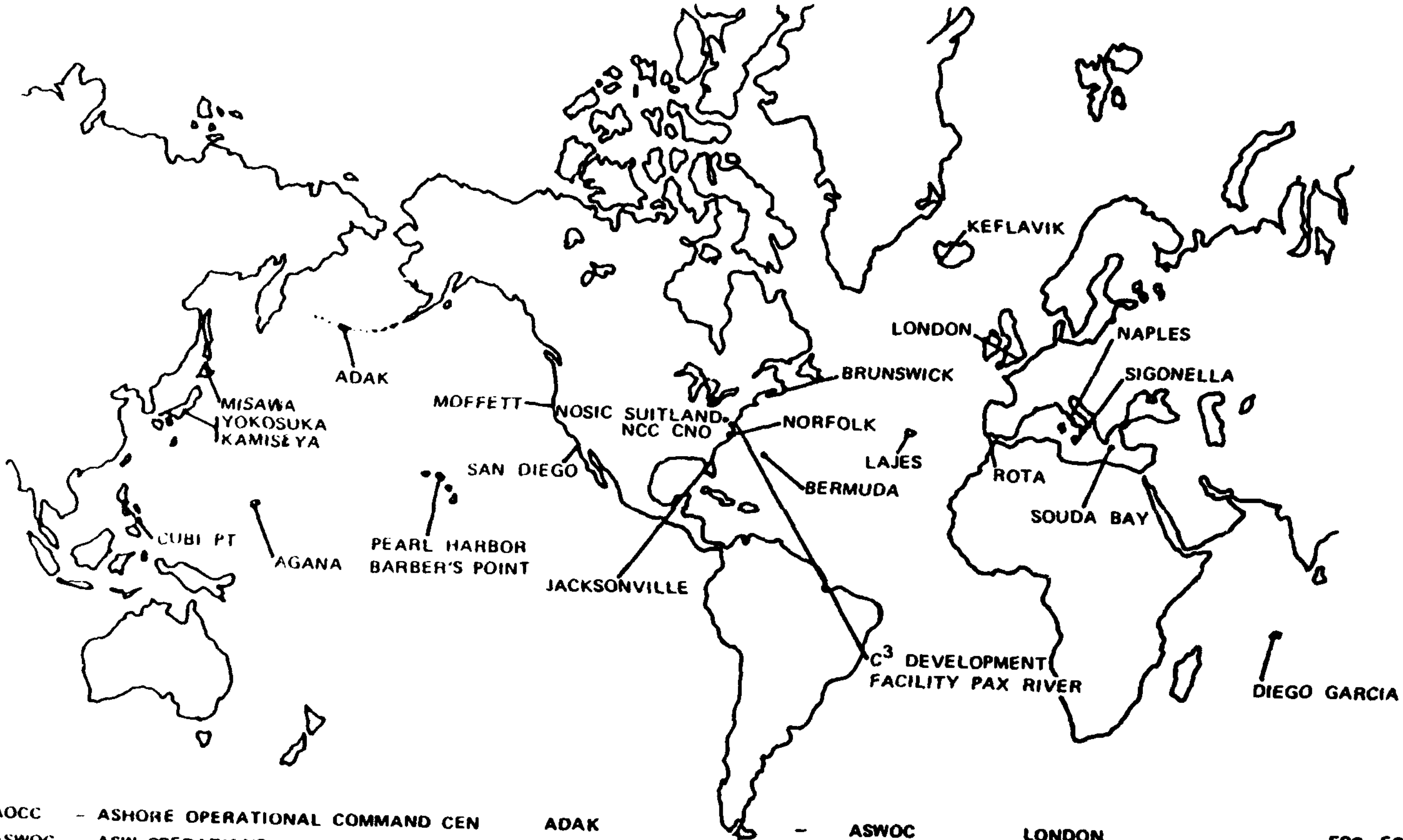
- 1 ASHORE SYSTEM/SUBSYSTEM R&D NODE

  C^2 ENGINEERING DEVELOPMENT AND
  SYSTEM PROTOTYPE FACILITY

- 7 SYSTEMS/SUBSYSTEMS AMONG THE 35 ASHORE NODES

  NWSS
  FHLT
  HLT
  IID
  ADS
  OSIS BASELINE
  OCPH

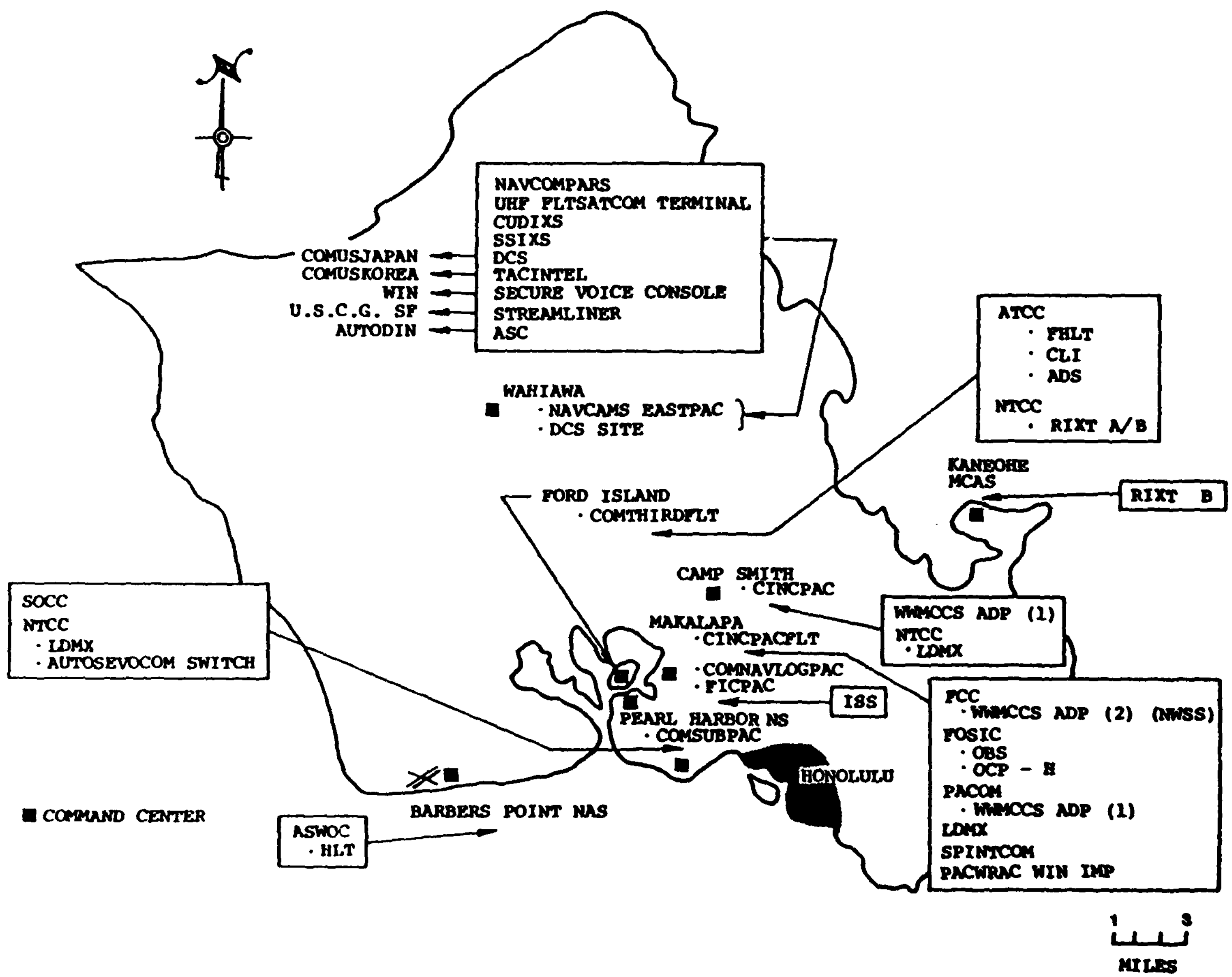
NESEC-V
CODE 340



AOCC - ASHORE OPERATIONAL COMMAND CEN
ASWOC - ASW OPERATIONS CENTER
ATCC - ASHORE TACTICAL COMMAND CENTER
FOSIC - FLEET OCEAN SURVEILLANCE INFO CEN
FOSIF FLEET OCEAN SURVEILLANCE INFO FAC
FCC - FLEET COMMAND CENTER
NCC - NAVAL COMMAND CENTER
NOSIC NAVAL OCEAN SURVEILLANCE INFO CEN

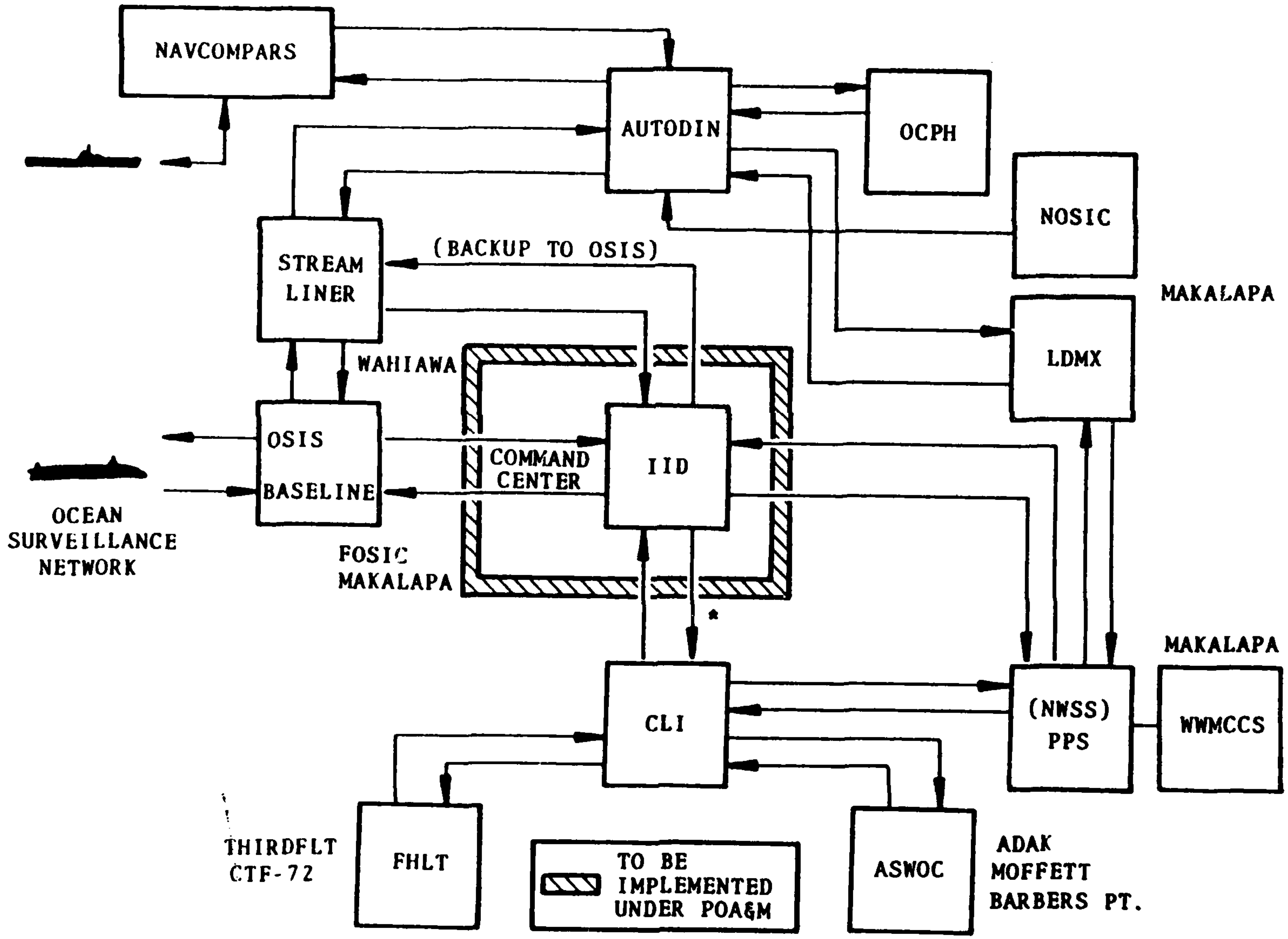
ADAK	– ASWOC
AGANA	– ASWOC
BARBER'S POINT	– ASWOC
BERMUDA	– ASWOC
BRUNSWICK	– ASWOC
CUBI PT	– ASWOC
DIEGO GARCIA	– ASWOC
JACKSONVILLE	– ASWOC
KADENA	– ASWOC
KAMISEYA	– ATCC, FOSIF
KEFLAVIK	– ASWOC
LAJES	– ASWOC

LONDON	– FCC, FOSIC
MISAWA	– ASWOC
MOFFETT	– ASWOC
NAPLES	– ATCC, AOCC
NORFOLK	– AOCC, FCC, FOSIC
PEARL HARBOR	– AOCC, ATCC, FCC, FOSIC
ROTA	– ASWOC, FOSIF
SAN DIEGO	– AOCC
SIGONELLA	– ASWOC
SOUDA BAY	– ASWOC
YOKOSUKA	– AOCC



NAVAL COMMAND CENTERS (OAHU)

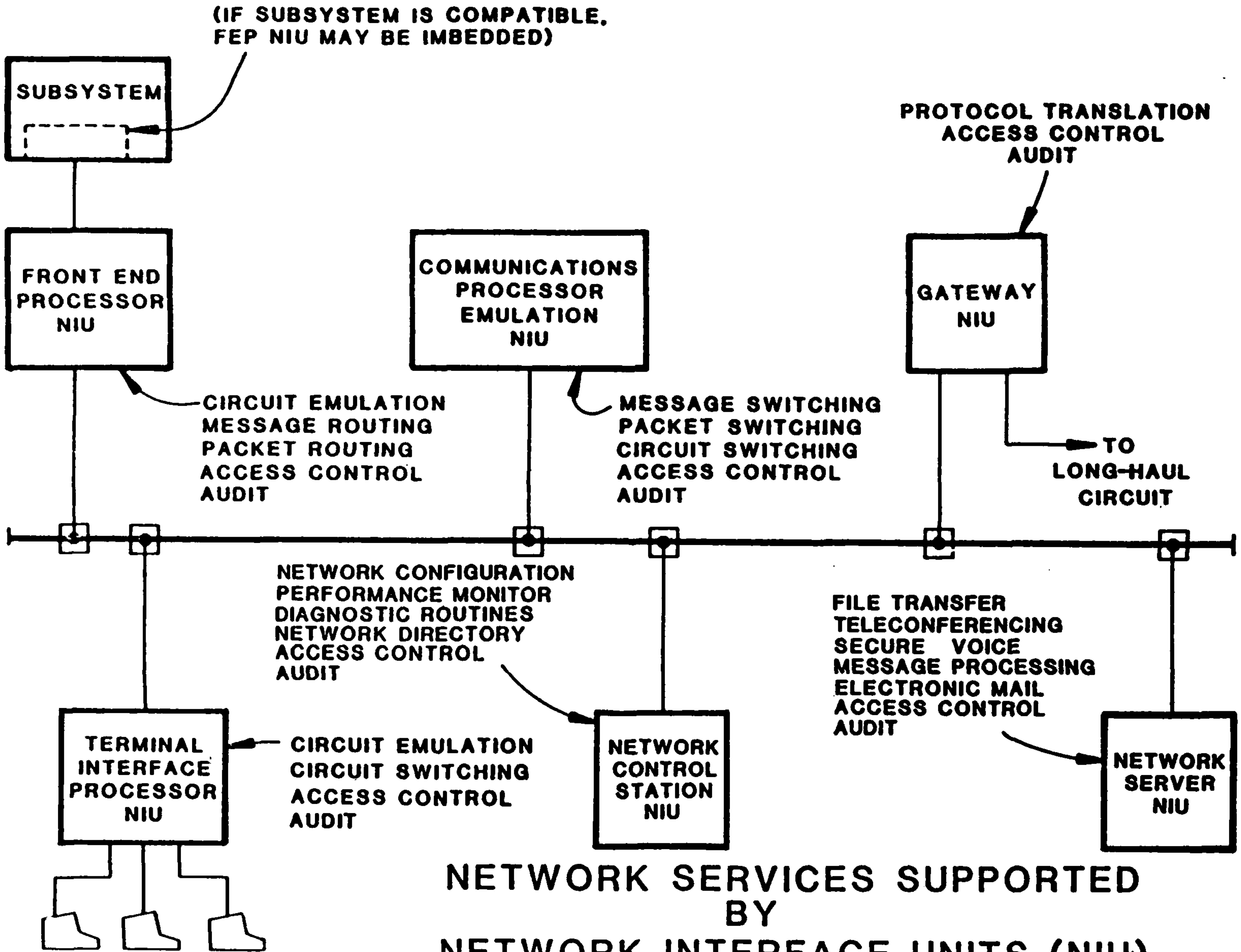
IID SYSTEM INTERFACES



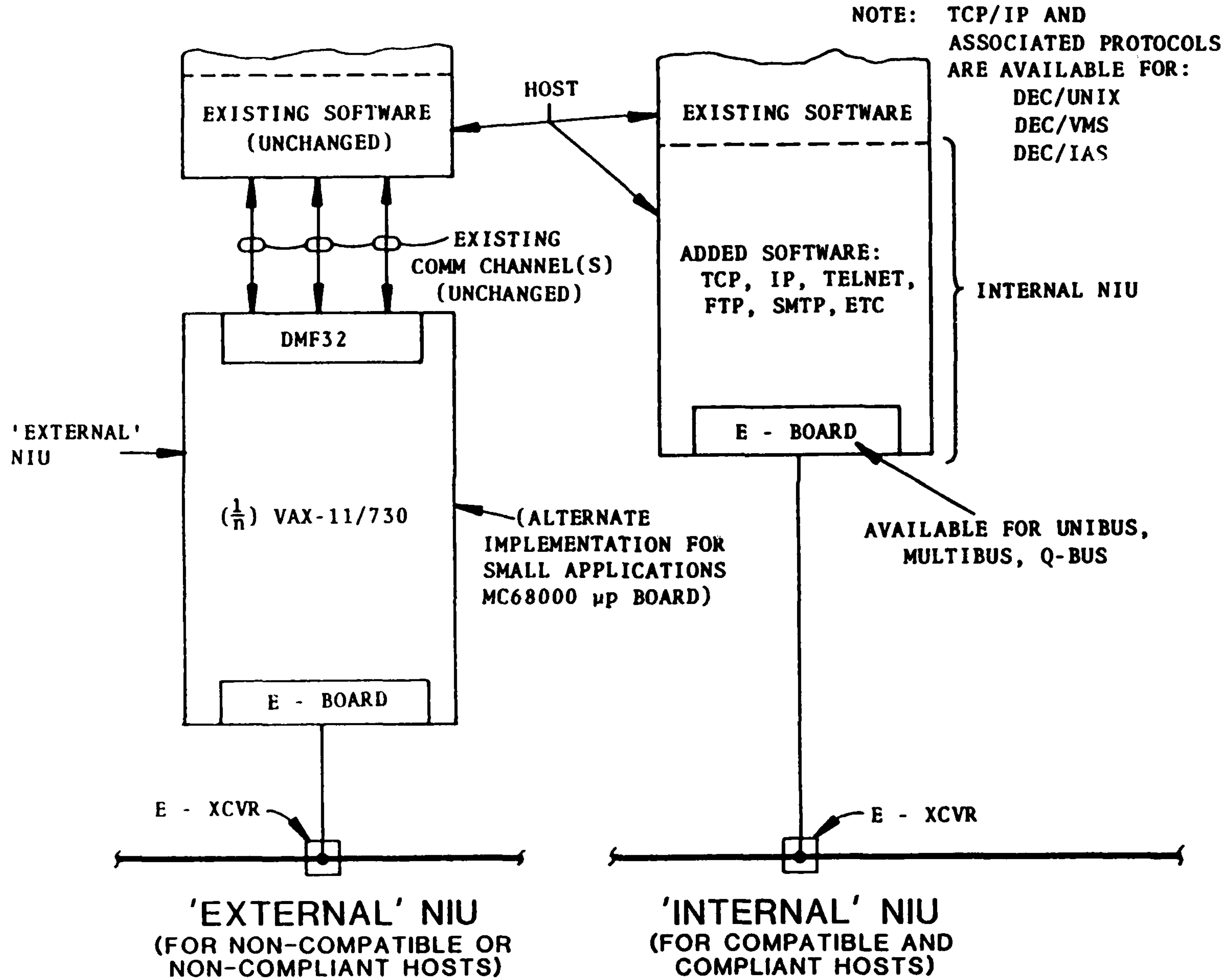
*LINK REQUIRES A SECURITY WAIVER MANUAL CONNECT/DISCONNECT

ISP DESIGN CONCEPT

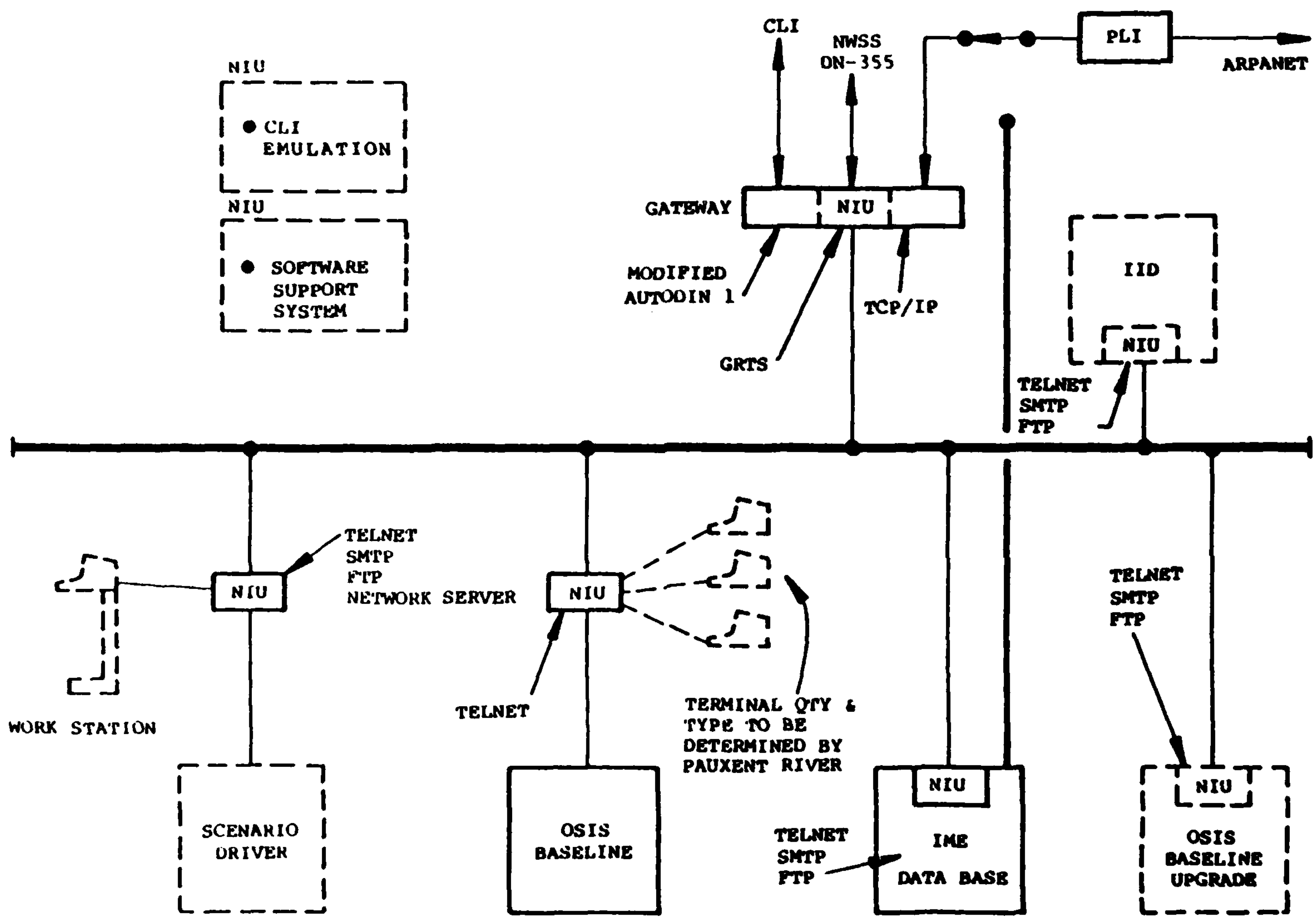
- Δ INTERNAL AND EXTERNAL NETWORK INTERFACE UNITS
- Δ MULTIPLE EXTERNAL NIU CONFIGURATIONS
- Δ DOD PROTOCOL STANDARDS (TCP/IP)
- Δ PROTOCOL TECHNOLOGY TRANSITION
- Δ VAX-11/730/750/780
- Δ UNIX OPERATING SYSTEM
- Δ ETHERNET (10 Mb/s)



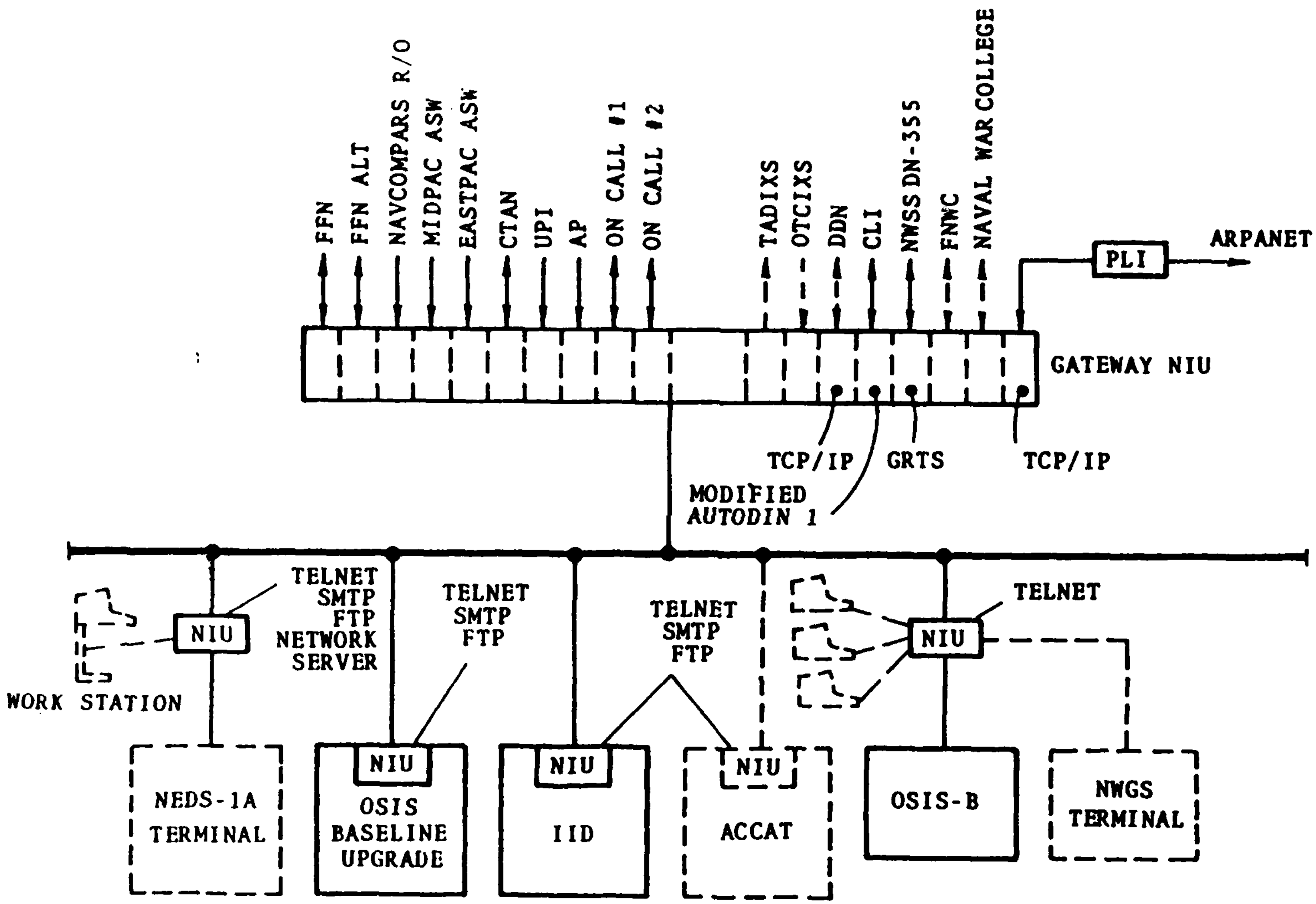
NETWORK SERVICES SUPPORTED BY NETWORK INTERFACE UNITS (NIU)



NOTE: TCP/IP AND ASSOCIATED PROTOCOLS ARE AVAILABLE FOR:
DEC/UNIX
DEC/VMS
DEC/IAS
EXISTING SOFTWARE (UNCHANGED)
HOST
EXISTING SOFTWARE
ADDED SOFTWARE: TCP, IP, TELNET, FTP, SMTP, ETC
INTERNAL NIU
EXISTING COMM CHANNEL(S) (UNCHANGED)
DMF32
'EXTERNAL' NIU
($\frac{1}{n}$) VAX-11/730
(ALTERNATE IMPLEMENTATION FOR SMALL APPLICATIONS MC68000 μp BOARD)
E - BOARD
E - BOARD
AVAILABLE FOR UNIBUS, MULTIBUS, Q-BUS
E - XCVR
E - XCVR
'EXTERNAL' NIU
(FOR NON-COMPATIBLE OR NON-COMPLIANT HOSTS)
'INTERNAL' NIU
(FOR COMPATIBLE AND COMPLIANT HOSTS)



ISP TEST AND EVALUATION AT EDSPF PATUXENT RIVER



ISP TEST & EVALUATION AT CINCPACFLT COMMAND CENTER

IMPACT OF FIBER OPTICS
ON
LOCAL AREA NETWORKS

S. BALSERA P. STEENSMA

ITT DEFENSE COMMUNICATIONS
NUTLEY, NEW JERSEY

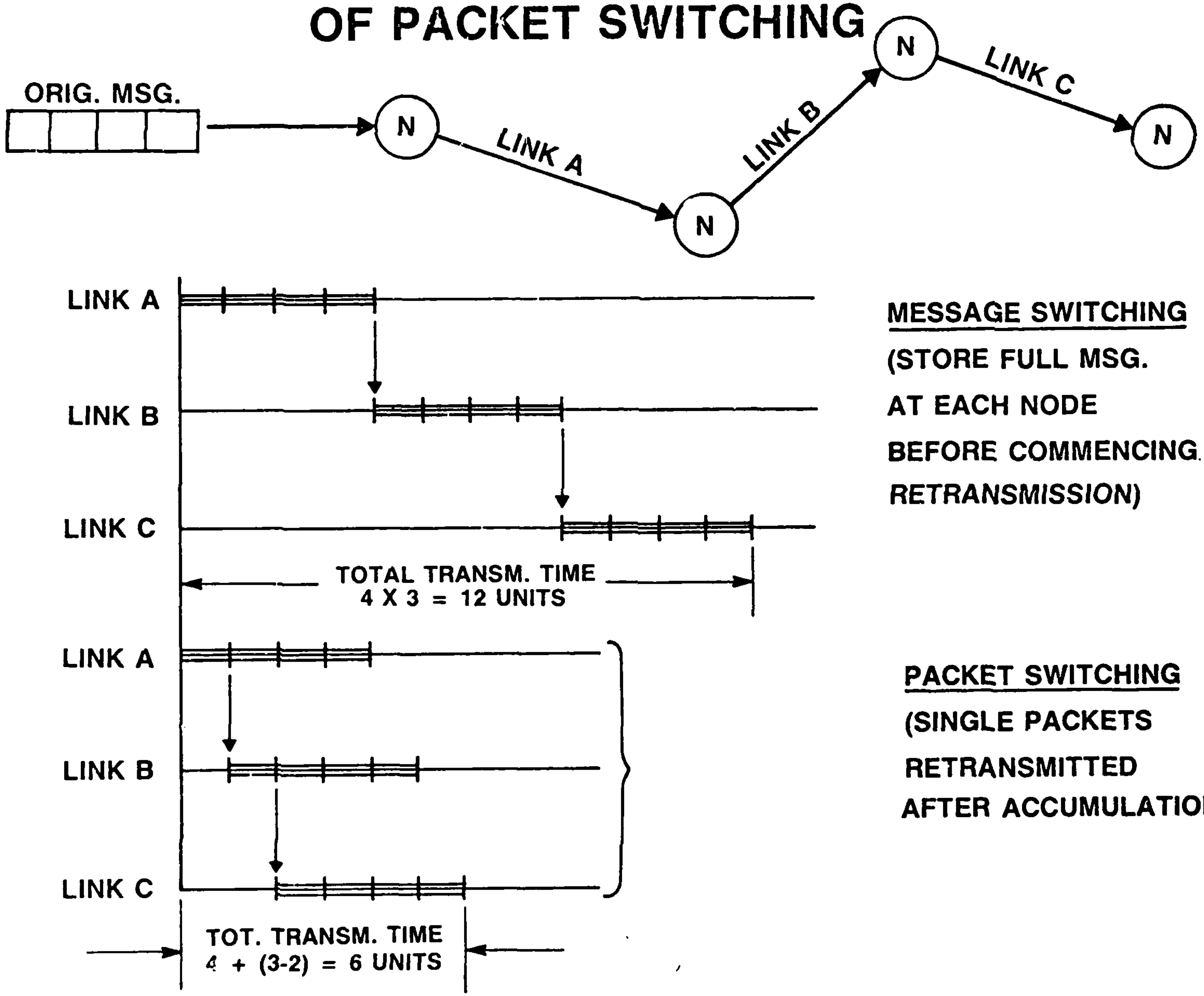
LAN DEFINING CHARACTERISTICS

- SMALL AREA COVERED $\sim$ 1KM
- HIGH DATA RATES $>$ 1 MBPS
- USER AUTONOMY AND INTELLIGENCE

LONG HAUL VS LAN CHARACTERISTICS

PARAMETER	LONG HAUL	LAN
NETWORK OWNER	COMMON CARRIERS	USER
COVERAGE	TENS TO THOUS. KMS.	5 KM
TRANSMISSION BANDWIDTH	92 KBS	3200 MBS
NETWORK TRANSIT DELAY	0.3- 2 SEC.	25 SEC.
BIT ERROR RATE	$10^{-4} - 10^{-6}$	$10^{-6} - 10^{-9}$
NUMBER OF HOPS	3 - 6	1
NODE CONNECTIVITY	LIMITED	FULL
TRANSMISSION COST	VERY HIGH	VERY LOW

THE TRANSMISSION PIPELINING EFFECT OF PACKET SWITCHING



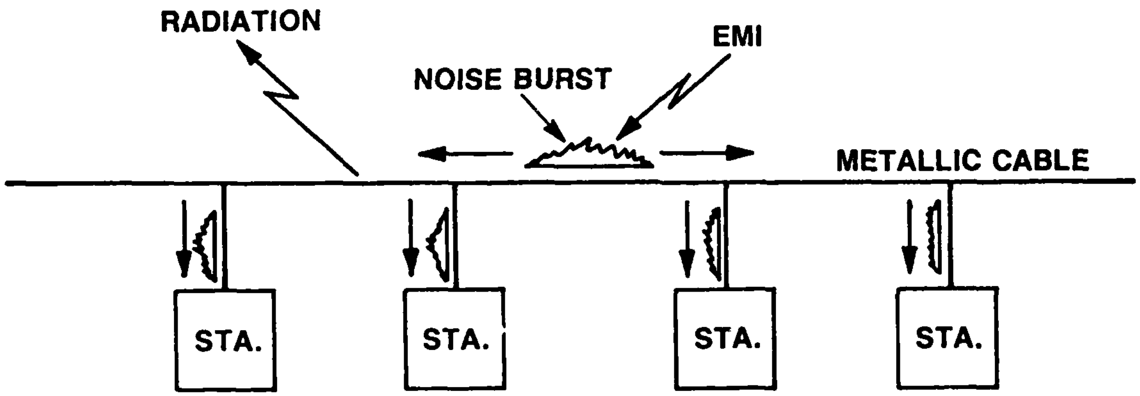
MESSAGE SWITCHING
(STORE FULL MSG.
AT EACH NODE
BEFORE COMMENCING
RETRANSMISSION)

PACKET SWITCHING
(SINGLE PACKETS
RETRANSMITTED
AFTER ACCUMULATION)

KEY CHARACTERISTICS OF FIBER OPTIC LAN ENVIRONMENT

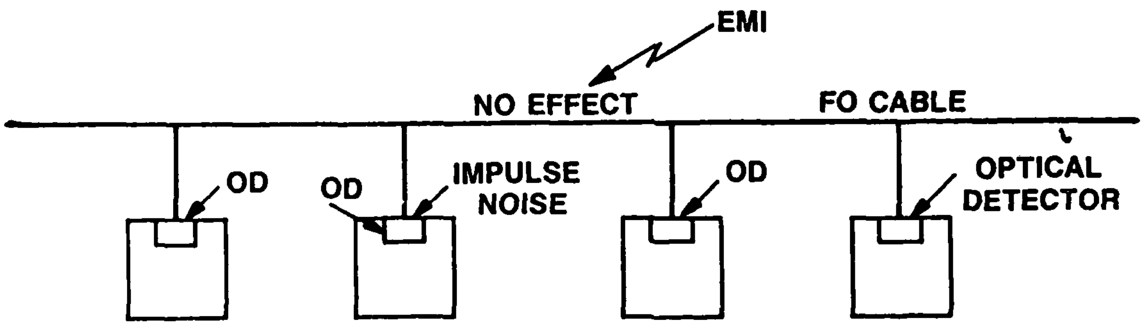
- SIMPLE TOPOLOGY
  - POWER LIMITED
- ERRORS ARE
  - LOW
  - LOCALIZED IN TIME AND SPACE
- LOW INTERUSER DELAY
- ECONOMIC LARGE BANDWIDTH

METALLIC VS. FIBER OPTIC ERROR ENVIRONMENT



FEC INEFFECTIVE

- NOISE AFFECTS ALL STATION
- REQUIRES DOUBLE SPEED
- BURST ERRORS DIFFICULT TO CORRECT

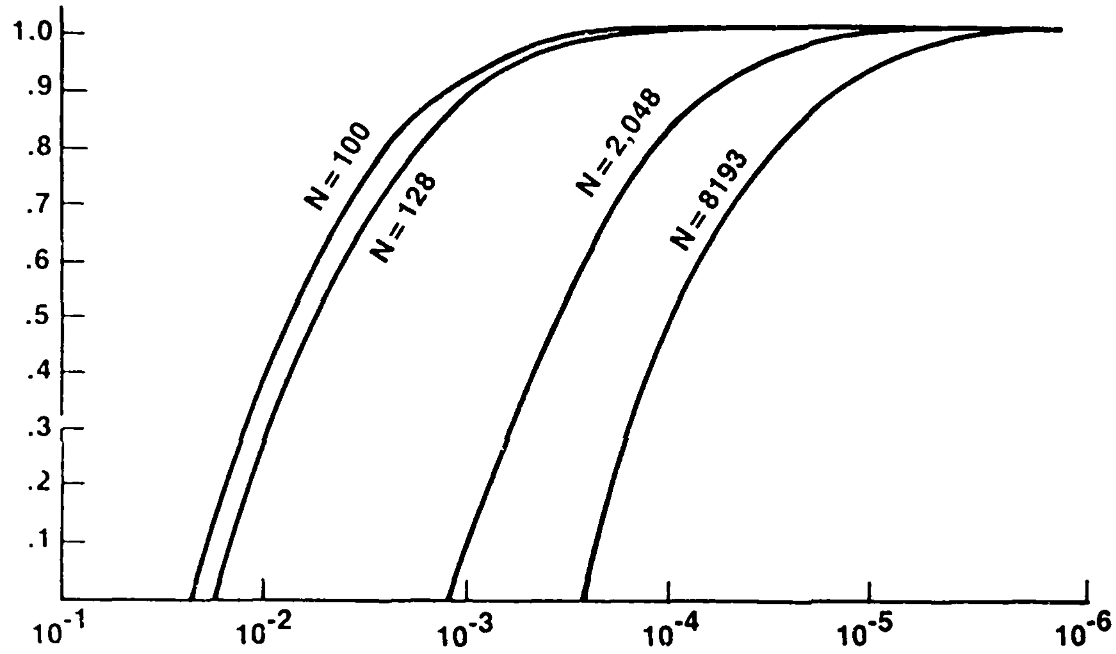


FEC EFFECTIVE

- NOISE AFFECTS ONLY ONE STATION
- BANDWIDTH AVAILABLE
- SINGLE BIT ERRORS
- LOW BER CHANNEL

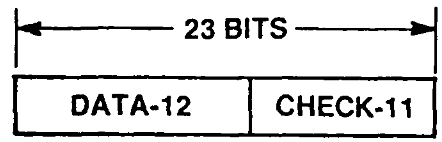
ERROR CONTROL TECHNIQUES

AUTOMATIC REPEAT REQUEST



FORWARD ERROR CORRECTION

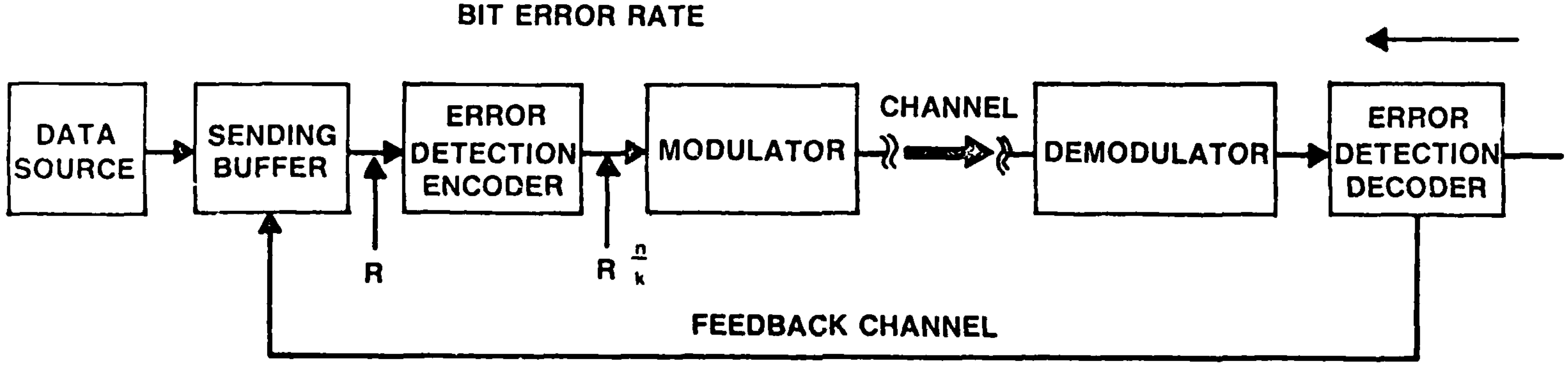
GOLAY



DETECT 4 ERROR IN 23

CORRECT 3 ERROR IN 23

THRUPUT = 1/2



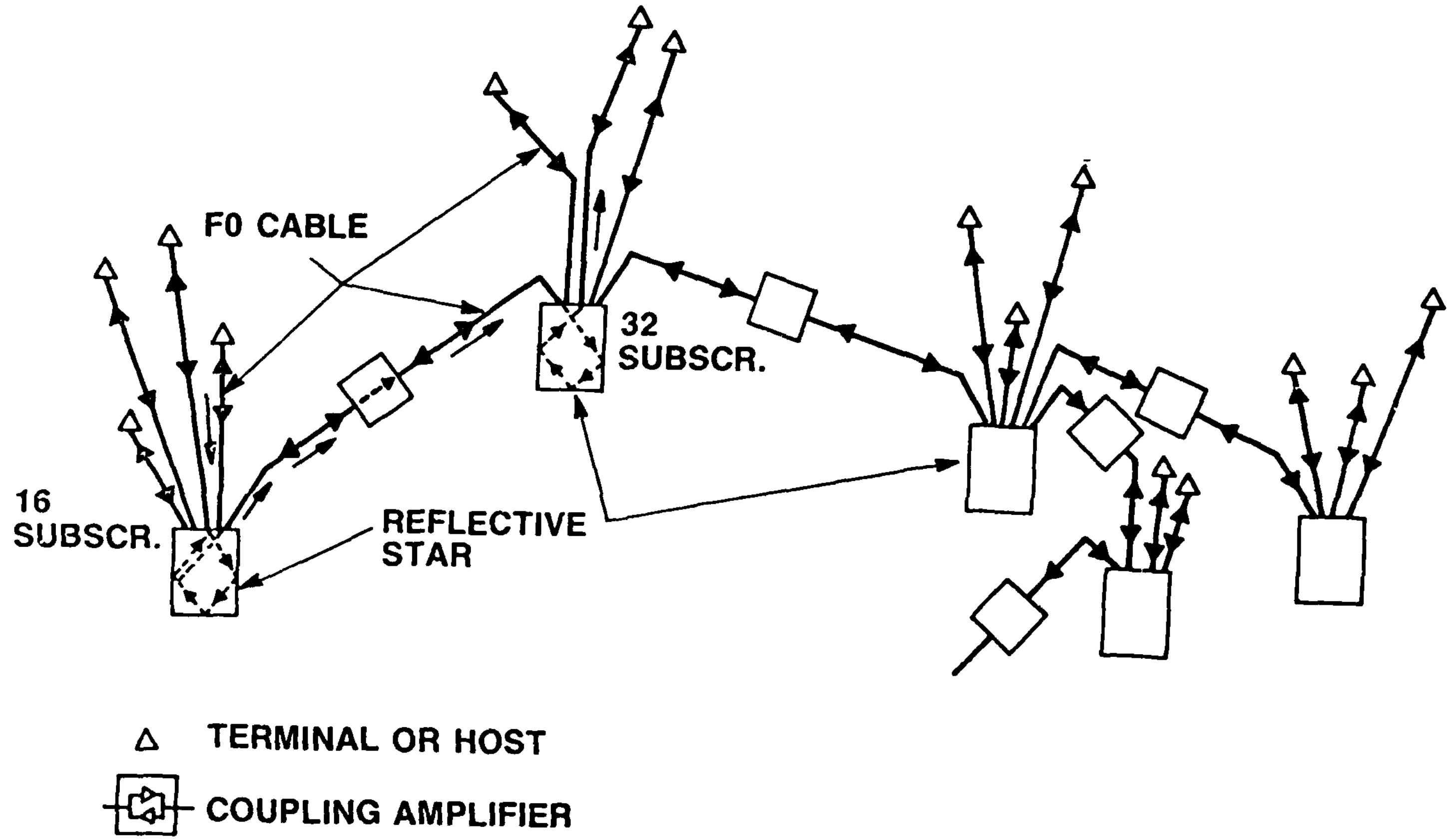
ELEMENTS OF AN ARQ SYSTEM

SIMPLIFICATIONS FROM FEC IN FO CABLES

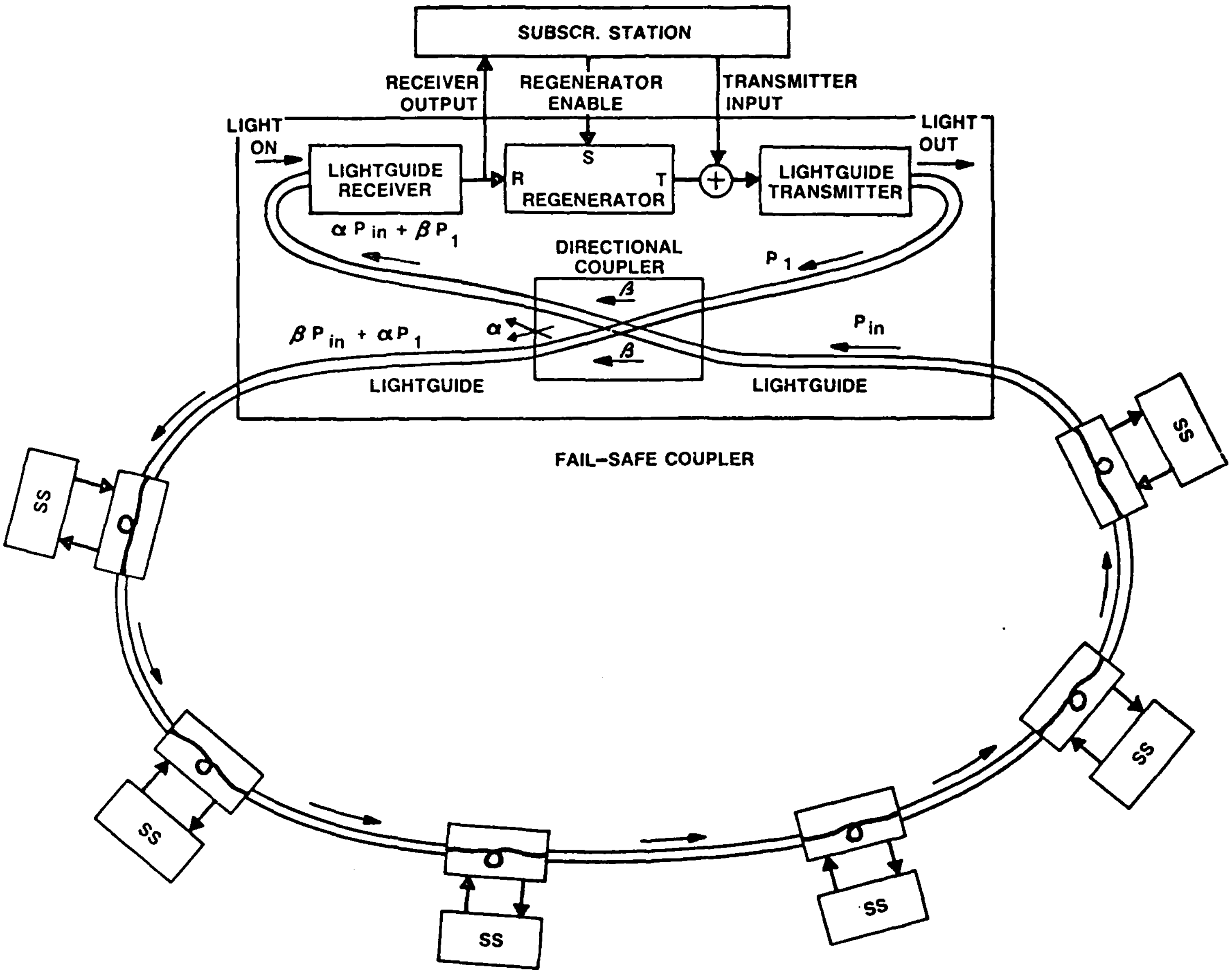
- SIMPLER LINK PROTOCOLS
- LOW BUFFER REQUIREMENTS (NO BUFFER HOLDING)
- ACK/NACK PROCESSING NOT REQUIRED
- PACKET SEQUENCE MAINTAINED
- MINIMUM DELAY VARIANCE
- CONVENIENT MULTI CAST

TOPOGOLY ALTERNATIVES

STAR

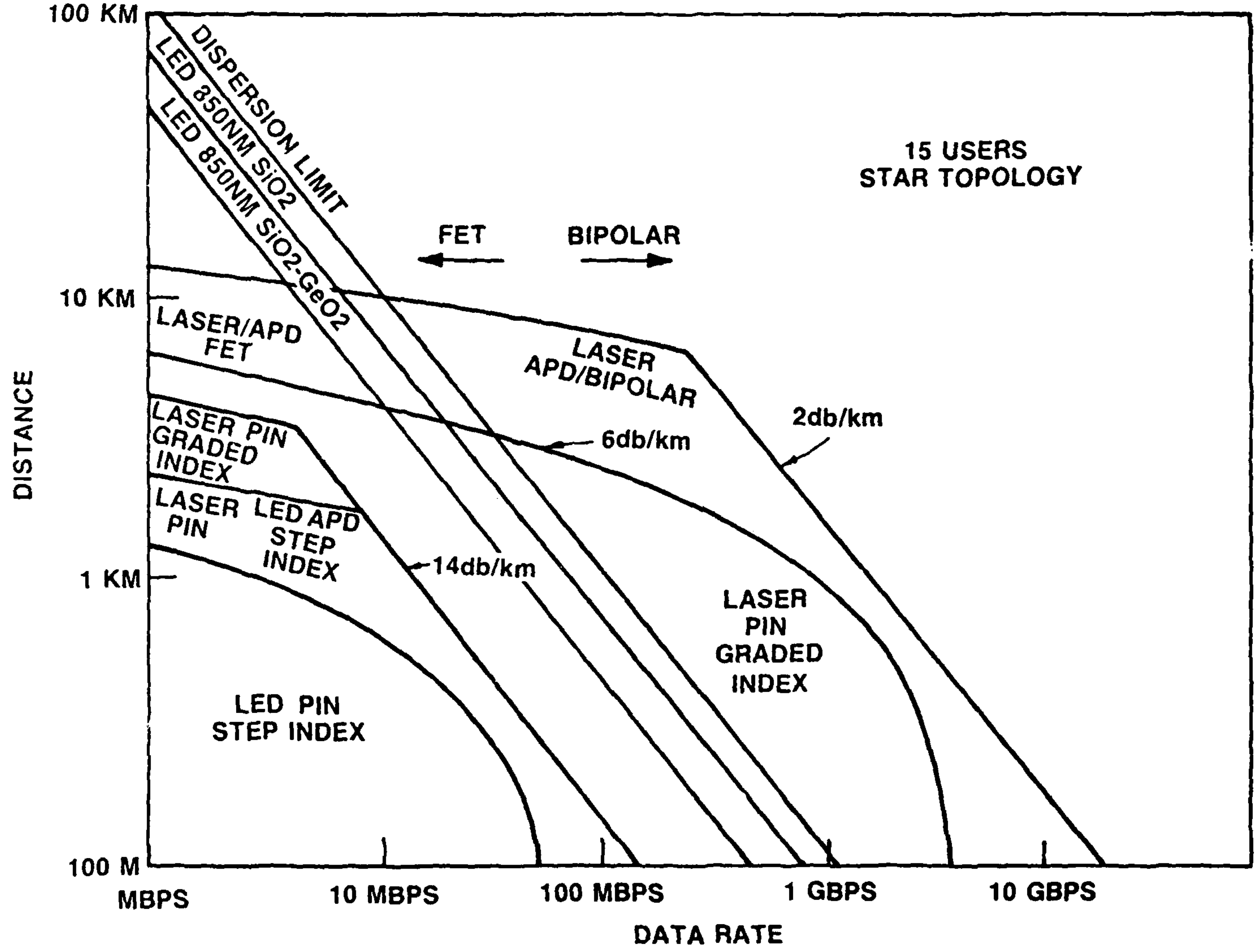


LINEAR RING



SUBSCR. STATION
RECEIVER OUTPUT
REGENERATOR ENABLE
TRANSMITTER INPUT
LIGHT ON
LIGHT OUT
LIGHTGUIDE RECEIVER
R
S
T
REGENERATOR
LIGHTGUIDE TRANSMITTER
$\alpha P_{in} + \beta P_1$
DIRECTIONAL COUPLER
β
β
α
P_1
P_{in}
$\beta P_{in} + \alpha P_1$
LIGHTGUIDE
LIGHTGUIDE
FAIL–SAFE COUPLER
SS
SS
SS
SS
SS
SS
SS

CAPABILITIES OF FIBER OPTIC MULTIPOINT DISTRIBUTION SYSTEMS



LOW DELAY IN FIBER OPTIC BUSES

- QUEUE WAIT TIME: ≈ 0
- TRANSMISSION TIME: 5-10 μSEC
- TIME OF FLIGHT: 5 μSEC/KM
- PACKET PROCESSING TIME: 5-10 MSEC
- NO STORE AND FORWARD
- NO QUEUE BUILDUP - HIGH SPEED BUS SERVER
  NEAR REAL TIME CONTROL
- NO NEED FOR PRECEDENCES

CONTROL IMPACT OF LOW DELAY

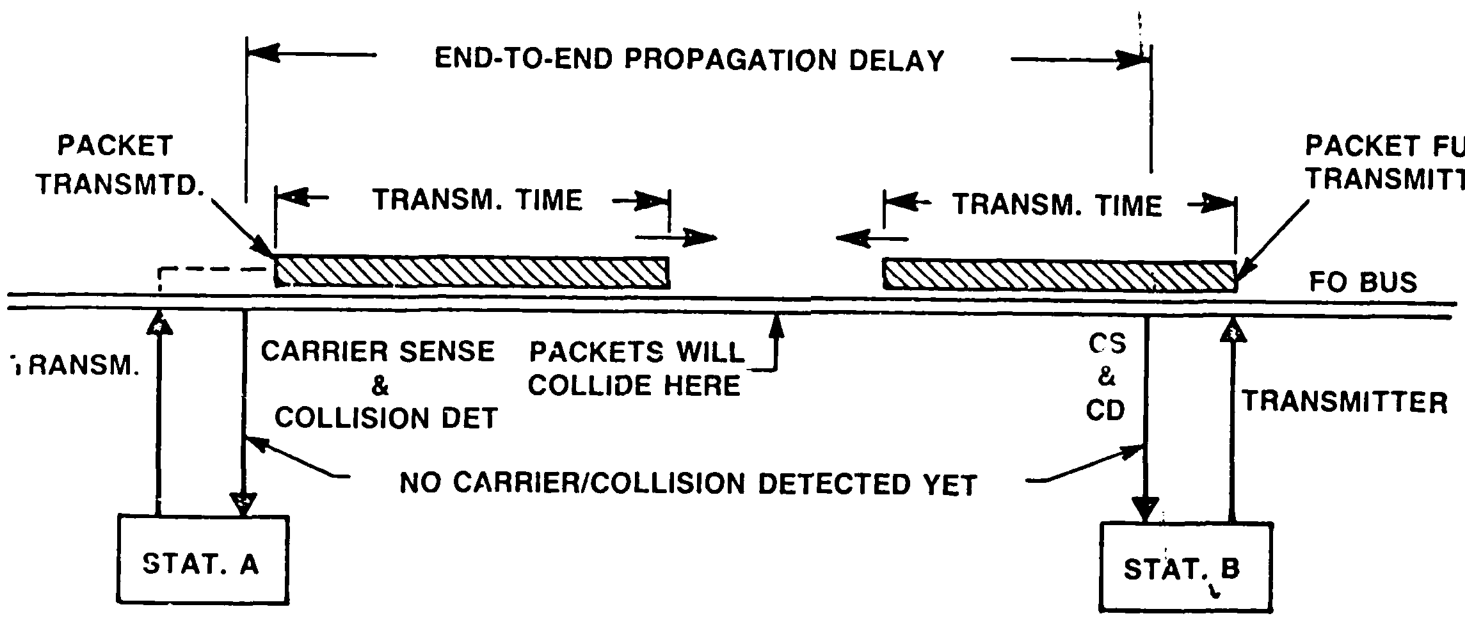
CONVERSATIONAL VS. TELEGRAM INTERACTION
FLOW CONTROL APPROACH

CONVENTIONAL	FIBER OPTIC
• WINDOW RESERVATION	• START/STOP
• PROCESSING INTENSIVE (MSG. RESEQUENCING)	• SIMPLE (AUTOMATIC SEQUENCE)
• SLOW CONTROL ACTION	• FAST CONTROL (SINGLE HOP + HI-SPEED)
• LOW BUFFER EFFIC. (BULK RESERVATION)	• HIGH BUFFER EFFICIENCY (SINGLE BUFFER RESERVATION)

BANDWIDTH IMPACT

- ALLOWS HIGH CAPACITY APPLICATIONS
  - "TELEPROCESSING"
  - TRUE MULTIPROCESSING - MOBILE SOFTWARE
  - VOICE
- DIFFERENT MULTIPLE ACCESS CONSTRAINTS
- SPEED GAP AND PROCESSOR BLOCKING

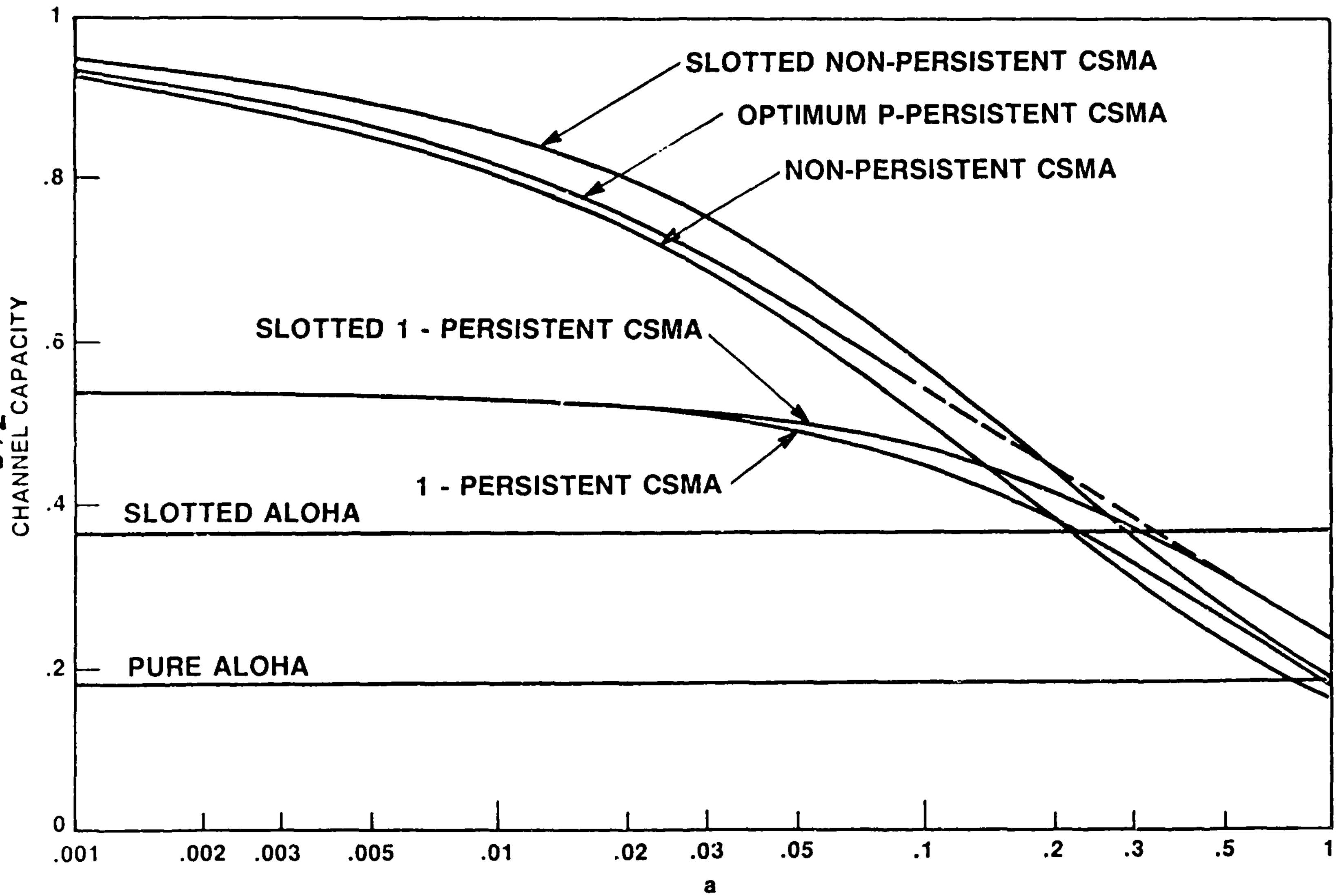
LIMITS ON CONTENTION BASED ACCESS



200 MB/S

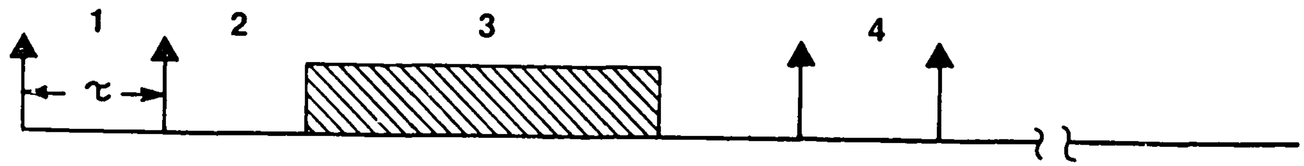
TRANSMISSION TIME FOR A 2000 BIT PACKET: 10 μSEC
PROPAGATION TIME FOR 1 KM CABLE: 5 μSEC
} a = 0.5

$$a = \frac{\text{END TO END PROPAGATION DELAY}}{\text{PACKET TRANSMISSION TIME}}$$

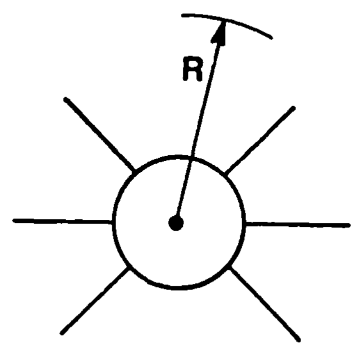

SLOTTED NON-PERSISTENT CSMA
OPTIMUM P-PERSISTENT CSMA
NON-PERSISTENT CSMA
SLOTTED 1 - PERSISTENT CSMA
1 - PERSISTENT CSMA
SLOTTED ALOHA
PURE ALOHA
CHANNEL CAPACITY
1
.8
.6
.4
.2
0
.001
.002
.003
.005
.01
.02
.03
.05
.1
.2
.3
.5
1
a

LIMITS ON DETERMINISTIC ACCESS

POLLING CYCLE = N

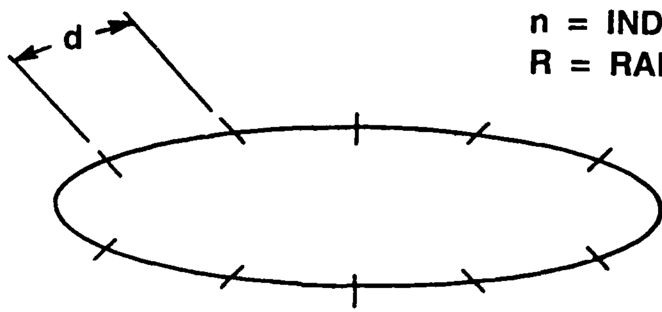


STAR $\tau = \frac{2Rn}{C}$

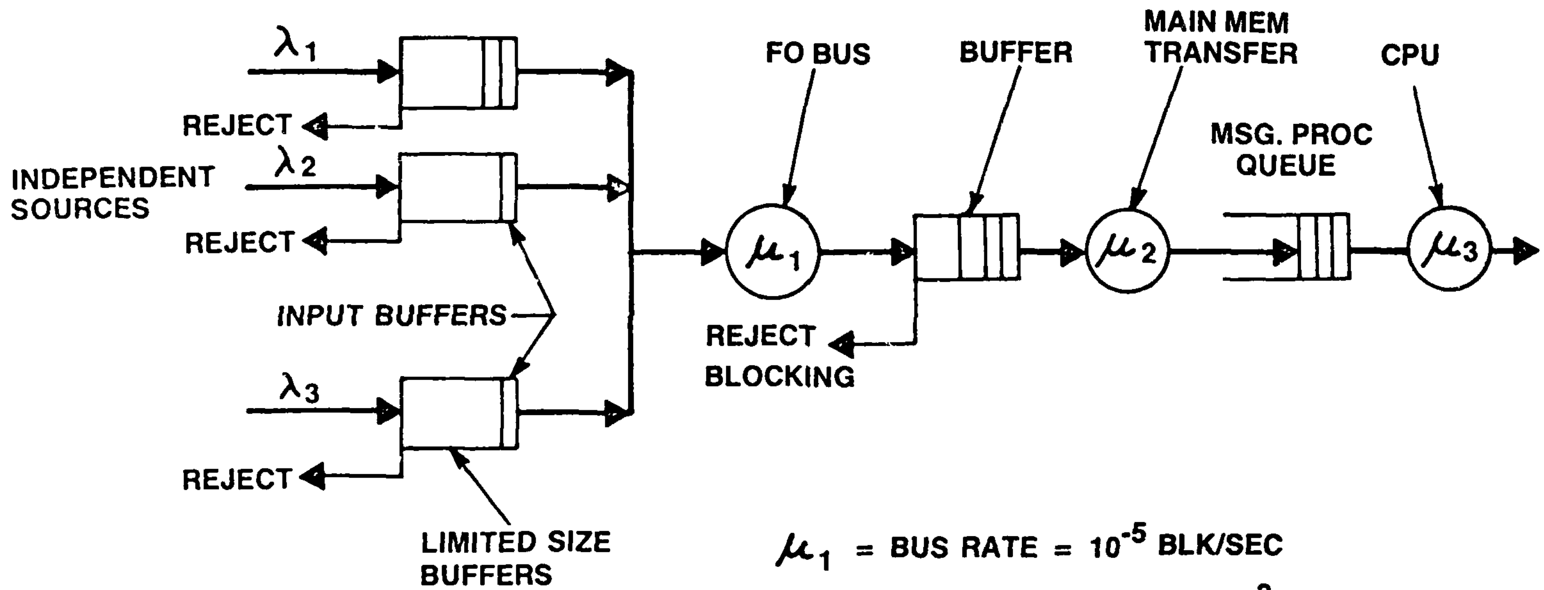


N = NO SUBSCRIBER
C = SPEED OF LIGHT
n = INDEX OF REFRACTION
R = RADIUS

RING $\tau = \frac{2dn}{C}$



QUEUEING MODEL FOR SUBSCRIBER BLOCKING ANALYSIS

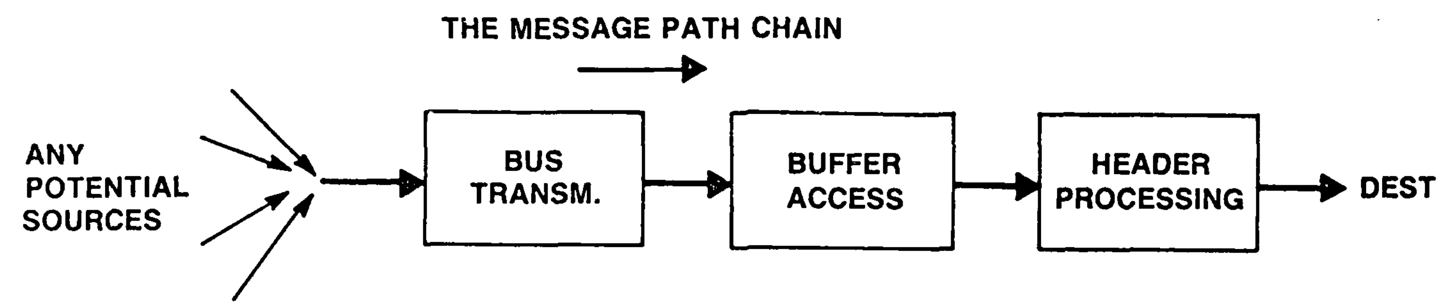


μ_1 = BUS RATE = 10^{-5} BLK/SEC

μ_2 = BUFFER RATE = 27 X 10^{-3}

μ_3 = HEADER PROCESSING RATE = 150 BLK/SEC

SUBSCRIBER BLOCKING IN VERY FAST BUSES



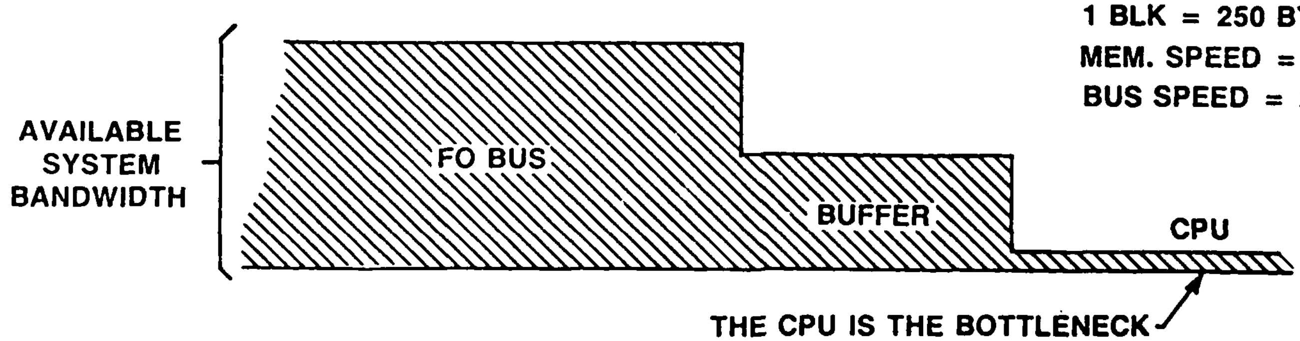
BUS RATE: $\frac{200\ \text{MBS}}{250 \times 8} = 100{,}000$ BLOCKS/SEC

BUFFER RATE: $\frac{1}{250 \times 150 \times 10^{-9}} = 27{,}000$ BLKS/SEC

PROCESSOR RATE: Z-80 $\approx$ 12 BLKS/SEC
Z-8000 $\approx$ 150 BLKS/SEC

ASSUME

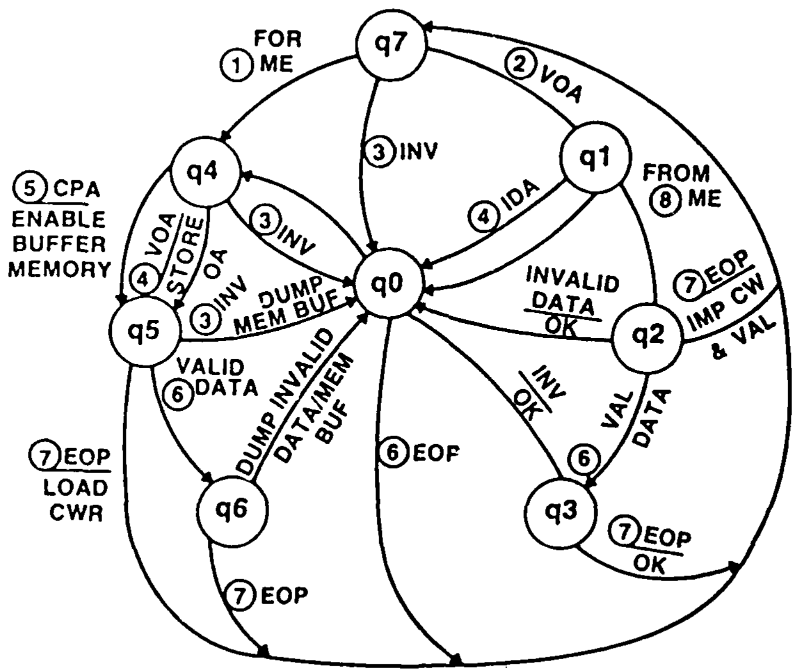
1 BLK = 250 BYTES
MEM. SPEED = 150 NSEC.
BUS SPEED = 200 MBS



CLOSING THE SPEED GAP

- THROTTLE BUS — NEEDS MORE PROCESSING
  - WASTES BANDWIDTH
  - INCREASES DELAY
- CHANNELIZE BUS
  - WAVELENGTH MULTIPLEXING — TECHNOLOGY DEVELOPMENT
  - CARRIERS (BROADBAND) — SHOT NOISE LOADING
  - WORD ORIENTED TDM — AVAILABLE TECHNOLOGY
- SPECIAL PURPOSE PROCESSORS (HIGH SPEED STATE MACHINE) — LIMITS PROTOCOL SOPHISTICATION
- MESSAGE TRANSACTION VS. PACKET - FEWER HEADERS

STATE MACHINE APPROACH TO PROTOCOL



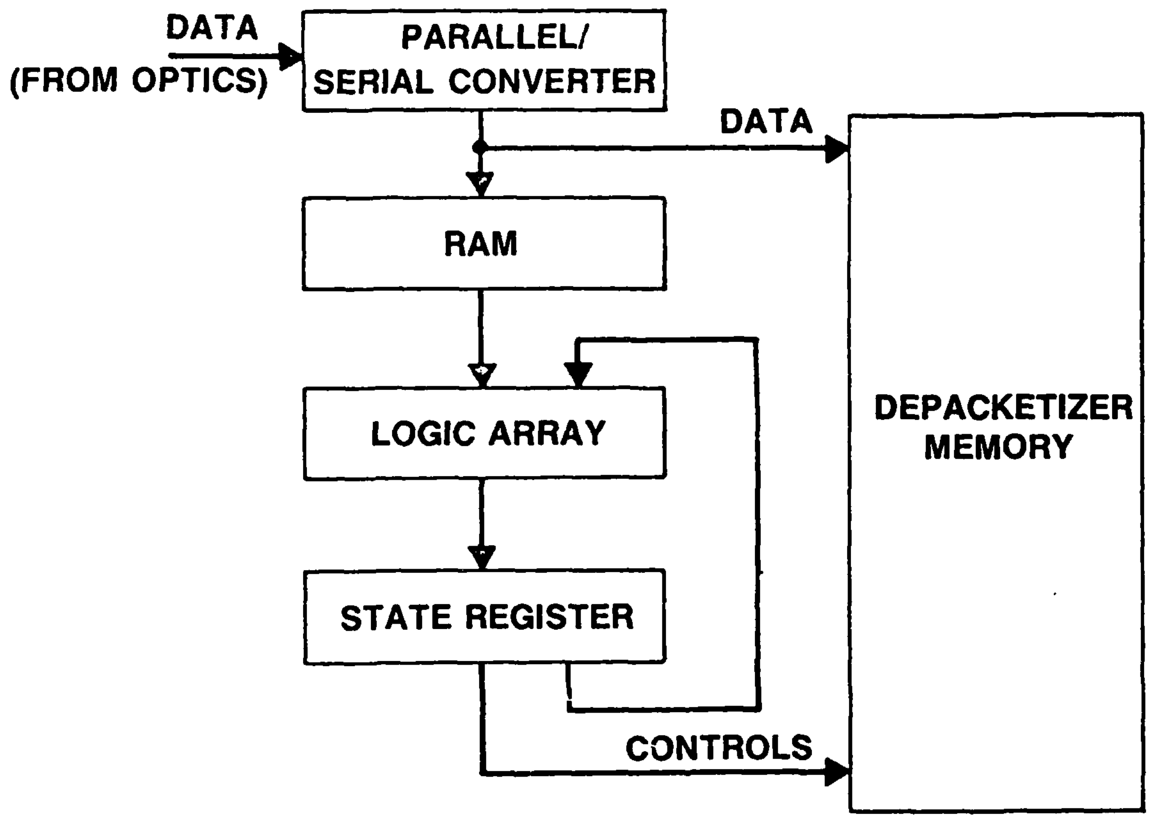
DETECTED CONDITIONS

1	FOR ME	– THIS BIU'S DESTINATION ADDRESS
2	VDA	– VALID DESTINATION ADDRESS
3	INV	– INVALID DATA
4	VOA	– VALID ORG ADR
5	CPA	– CONNECTED PARTY ADDRESS
6	VAL DATA	– VALID DATA
7	EOP	– END OF PACKET
8	FROM ME	– THIS BIU'S ORGINATION ADDRESS

OUTPUTS

ENABLE BUFFER MEMORY	– ENABLE DATA TO BE STORED IN BUFFER
DUMP MEM BUF	– CLEAR DATA PREVIOUSLY STORED FROM THIS PACKET
LOAD CCWR	– STORE CONTROL WORD AND NOTIFY CONTROLLER
OK	– NOTIFY COTROLLER NO ERRORS IN THIS BIU'S LAST TRANSMISSION
OK	– NOTIFY CONTROLLER ERRORS DETECTED IN THIS BIU'S LAST TRANSMISSION

HIGH SPEED STATE MACHINE



CONCLUSIONS

- FIBER OPTIC TECHNOLOGY PROVIDES A UNIQUE LAN
  COMMUNICATIONS ENVIRONMENT

- IMPLIES

  SIMPLIFIED CONTROL PROTOCOLS

  - ERROR
  - FLOW
  - ACCESS

- PROCESSOR LIMITED SYSTEM:

  REQUIRES CAREFUL SYSTEM DESIGN

Implementation II (1600-1730 29 Sep)

Session Chairman: Mr. John McNamara - RADC/OCDS

"Issues Influencing Tactical Local Area Network Implementation,"
Lt Gregory Swietek, Rome Air Development Center

Disscussion of specific issues which must be addressed during the successful implementation of Loacal Area Networks in a tactial environment.

"A Control System Architecture for Tactical Radar Networks,"
Dr. G. Lucas and Mr. T. Burke, Decision Science Applications Inc.

A methology and example of a user friendly network control concept will be presented.

"Implementation of a Local Network for Tactical Systems," Mr. Ron Foss, Sperry Univac

Experience gained in building a local area network in the tactical environment will be presented.

"A Conceptual Local Area Communications Network for a Distributed, Modular Operations Center," Mr. Gerhard Pfister, ITT Gilfillan

A practical application of a local area communicative network to a modular tactical system will be presented.

- LAN REQUIREMENTS OF SURVEILLANCE INTERNETTING
  - ALLOCATION AND PRIORITIZATION OF RESOURCES
  - FORMAL AND INFORMAL INFORMATION FLOW
  - PHYSICAL SECURITY
  - USER ACCEPTANCE AND UTILIZATION

O PRIORITIZATION OF RESOURCES, TARGETS, AREAS

- O NECESSARY FOR RESOURCE ALLOCATION
- O MAINTAIN "BEST POSSIBLE" LEVEL OF PERFORMANCE
- O CANDIDATE VALUE-DRIVEN ALGORITHM BY DSA

- RESOURCE ALLOCATION RESPONSIVE TO ENVIRONMENT
  - SUPPORTS EMCON
  - CAPITALIZE ON OVERLAPPING COVERAGE
  - MAINTAIN PERFORMANCE IN A DEGRADED ENVIRONMENT

- FORMAL AND INFORMAL INFORMATION REQUIREMENTS
  - TACS DEFINES FORMAL INFORMATION REQUIREMENTS
  - LAN MUST CAPTURE "BIG ROOM" ATMOSPHERE
  - INFORMAL INFORMATION FLOW IS IMPORTANT

- O PHYSICAL SECURITY REQUIREMENTS
  - O RECONFIGURABILITY, REINITIALIZATION
  - O REDUNDANCY
  - O MINIMIZE EXPLOITABILITY

- USER ACCEPTANCE AND UTILIZATION REQUIREMENTS
  - LAN MUST BE INTUITIVE TO USER
  - "FAILSAFE" TO HIGHEST POSSIBLE DEGREE
  - LAN MUST SUPPORT NOVICE AND SOPHISTICATE
  - FLEXIBILITY [illegible] TASK PROSECUTION

DSA

DSA 437

A CONTROL SYSTEM ARCHITECTURE FOR FUTURE TACTICAL RADAR NETWORKS

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1901 N. MOORE STREET, SUITE 1000
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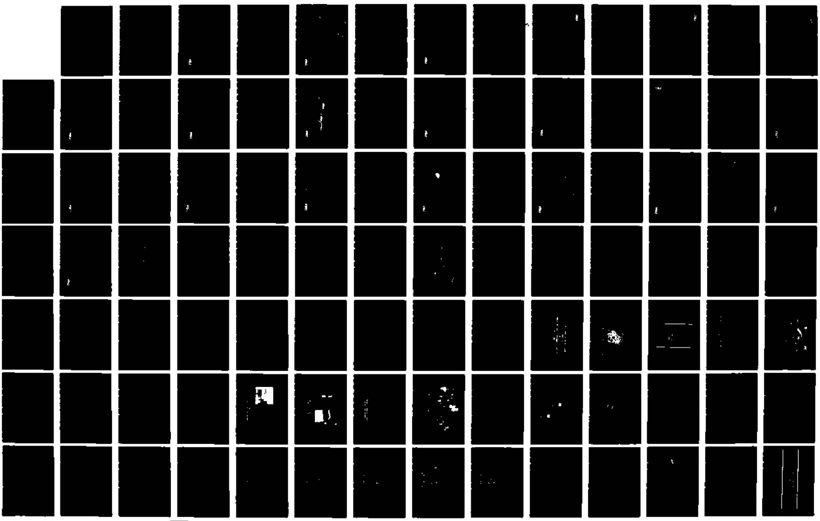
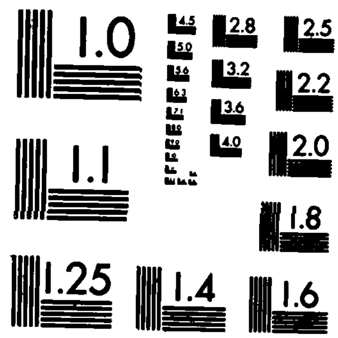
SEPTEMBER 29, 1982

AD-A126 110 PROCEEDINGS OF CONFERENCE ON LOCAL AREA MILITARY NETWORKS GRIFFISS AFB NEW YORK 28-30 SEPTEMBER 1982(U) ROME AIR DEVELOPMENT CENTER GRIFFISS AFB NY D B WARMUTH ET AL. 1982 5/6

UNCLASSIFIED F/G 17/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TITLE

MY PRESENTATION DISCUSSES OUR RECENT WORK IN DEVELOPING A CONTROL SYSTEM ARCHITECTURE FOR FUTURE TACTICAL RADAR NETWORKS. THIS WORK WAS PERFORMED FOR RADC AS PART OF THE SURVEILLANCE INTERNETTING AND IDENTIFICATION PROGRAM. FROM THE NUMBER OF PROGRAMS ADDRESSING THE ISSUE, ONE CAN CONCLUDE THAT THERE IS WIDESPREAD RECOGNITION OF NEED FOR MULTI-RADAR OPERATIONS -- BOTH TO COUNTER THE GROWING ELECTRONIC THREAT AND TO REALIZE THE FULL POTENTIAL OF THE CAPABILITIES WHICH WILL BE BUILT INTO ADVANCED TACTICAL RADARS.

THE CONTROL SYSTEM ARCHITECTURE WHICH WE HAVE DEVELOPED PROVIDES A METHODOLOGY FOR THE AUTONOMOUS CONTROL OF A NETWORK SUBJECT TO THE PRIORITIES OF THE OPERATORS.

I WILL OUTLINE OUR CONTROL SYSTEM ARCHITECTURE AND SHOW YOU SOME EXAMPLES OF THE CONTROL SYSTEM IN OPERATION ON OUR RADAR NETWORK SIMULATION.

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SURVEILLANCE SYSTEM OVERVIEW

LOOKING AT THE SURVEILLANCE SYSTEM OF THE FUTURE IT IS APPARENT THAT EACH INDIVIDUAL SENSOR WILL POSSESS TREMENDOUS CAPABILITY TO GATHER, PROCESS, AND COMMUNICATE LARGE AMOUNTS OF INFORMATION. THE ADVANCED TACTICAL RADAR WITH ITS AGILE BEAM AND MULTIPLE WAVEFORMS WILL HAVE THE CAPABILITY TO PERFORM A MULTITUDE OF ACTIVITIES IN ESSENTIALLY ANY ORDER DESIRED. THESE CAPABILITIES PROVIDE US WITH THE OPPORTUNITY TO BUILD INTELLIGENCE INTO OUR NETWORKS OF THE FUTURE.

WHILE THE ENTIRE SYSTEM CONTAINS MANY ELEMENTS, OUR WORK HAS THUS FAR CONCENTRATED ON INTELLIGENT CONTROL OF ADVANCED TACTICAL RADARS. FROM THE SYSTEM CHARACTERISTICS AS SHOWN ON THIS SLIDE, WE DERIVED THE DESIGN OBJECTIVES OF OUR CONTROL SYSTEM ARCHITECTURE.

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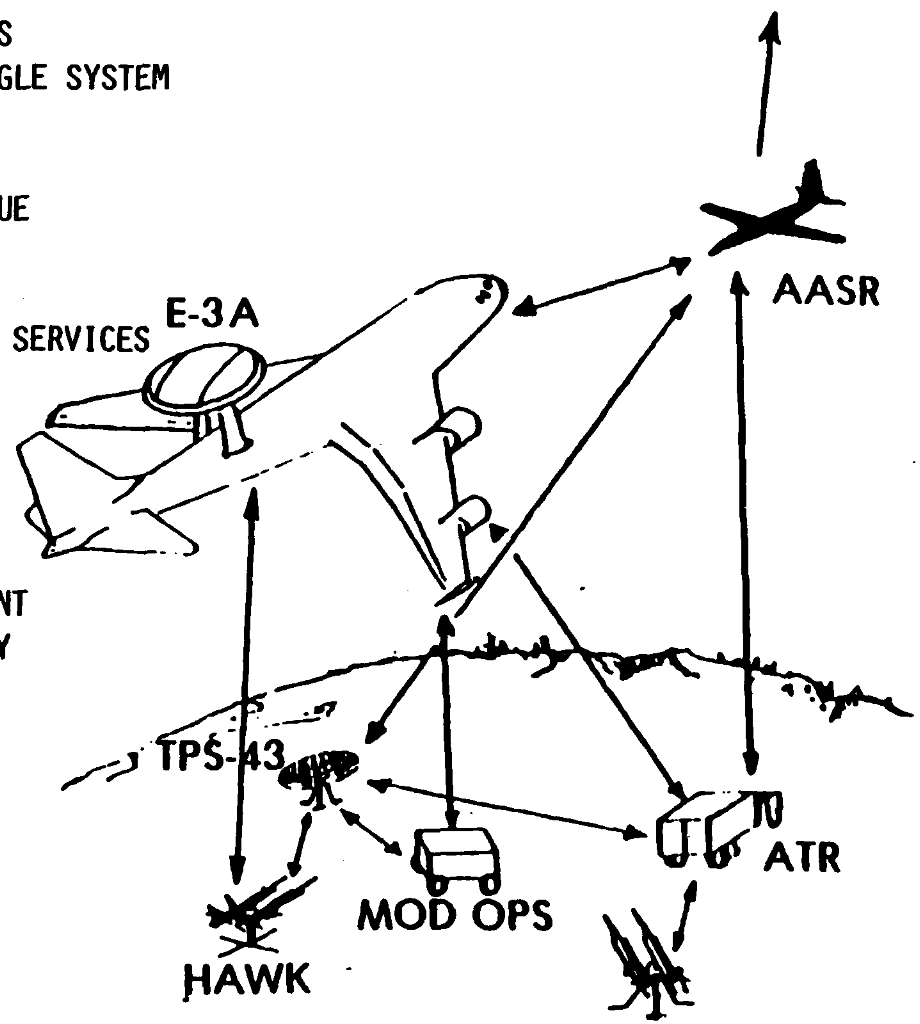
SYSTEM OVERVIEW

SYSTEM DESCRIPTION

- NETWORK OF SURVEILLANCE SYSTEMS
- OPERATED & CONTROLLED AS A SINGLE SYSTEM
- AUTOMATED & INTERACTIVE
- HIGHLY MOBILE & RELIABLE
- MODULAR WITH A MINIMUM OF UNIQUE HARDWARE
- USES NEW & EXISTING SENSORS
- AUTOMATED INTERFACE WITH OTHER SERVICES

SYSTEM FEATURES

- CONTINUOUS AUTOMATIC TRACKING
  - LOW LEVEL COVERAGE
- AUTOMATIC
  - SENIOR RESOURCE MANAGEMENT
  - DATA MANAGEMENT & DISPLAY
- MODULAR OPERATIONS CENTER
  - HIGHLY MOBILE
  - CBR PROTECTED
  - LOW POWER REQUIREMENTS



CONTROL SYSTEM DESIGN OBJECTIVES

THE PROJECTIONS OF THE THREAT WHICH WILL FACE THE ADVANCED TACTICAL RADAR ALL ENVISION A DENSE, RAPIDLY CHANGING ENVIRONMENT THAT WILL BE VIRTUALLY BEYOND THE CAPABILITIES OF HUMAN OPERATORS TO HANDLE. FOR THIS REASON, THE SYSTEM MUST OPERATE AUTONOMOUSLY, SUCH THAT WITHOUT HUMAN INTERVENTION IT WILL OPERATE IN A COMMON SENSE AND INTELLIGENT MANNER IN THE DENSE DYNAMIC ENVIRONMENT.

WHILE BEING CAPABLE OF OPERATING AUTOMATICALLY, THE CONTROL SYSTEM MUST BE RESPONSIVE TO OPERATOR PRIORITIES AND PREFERENCES. THE CAPABILITY MUST EXIST FOR THE OPERATOR TO ENTER NEW PRIORITIES IN AN EASY, STRAIGHTFORWARD, AND SIMPLE FASHION.

THE CONTROL SYSTEM DESIGN SHOULD MINIMIZE THE IMPACT UPON THE COMMUNICATIONS LOAD OF THE NETWORK.

SURVIVABILITY OF THE NETWORK FUNCTIONS IS A NECESSITY, AS IS THE CAPABILITY FOR GRACEFUL DEGREDATION AND GRACEFUL ENHANCEMENT OF THE FUNCTIONS AS ELEMENTS OF THE NETWORK BECOME INOPERATIVE OR REJOIN THE NETWORK.

NOT QUITE SO OBVIOUS IS OUR OBJECTIVE TO MAKE THE CONTROL SYSTEM CONCEPTUALLY SIMPLE AND INTUITIVE. WE BELIEVE THAT THE DEGREE OF ACCEPTANCE OF AUTOMATION CONCEPTS IS INVERSELY PROPORTIONAL TO THE COMPLEXITY OF THE CONCEPT.

FINALLY, STRONG EMPHASIS IS PLACED ON A PHILOSOPHY OF DESIGN WHICH COULD BE READILY GENERALIZED, EXTENDED, OR MODIFIED. GENERAL DESIGN PRINCIPLES WERE IDENTIFIED AND REAL OR ILLUSTRATIVE ALGORITHMS WERE DEVELOPED WHERE FEASIBLE. IN THIS WAY, WE BELIEVE THAT OUR CONTROL SYSTEM ARCHITECTURE CAN BE ADAPTED AS NECESSARY TO NEW AND DIFFERENT NETWORK CONCEPTS.

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CONTROL SYSTEM DESIGN OBJECTIVES

- OPERATES AUTONOMOUSLY
- RESPONSIVE TO OPERATOR PRIORITIES
- MINIMIZES COMMUNICATION LOAD
- ENHANCES SURVIVABILITY
- CONCEPTUALLY SIMPLE AND INTUITIVE
- READILY MODIFIED AND EXTENDED

IN DEVELOPING THE ARCHITECTURE FOR OUR CONTROL SYSTEM MANY ISSUES WERE CONSIDERED, THE MOST SIGNIFICANT OF WHICH ARE SHOWN ON THIS SLIDE.

MULTI-RADAR SEARCH AND TRACK, WHEREBY RADARS SHARE RESPONSIBILITIES, WAS TREATED IN DETAIL. RESPONSIBILITY FOR SEARCH AND TRACK WAS VARIED AUTOMATICALLY AMONG THE RADARS OF A NETWORK IN ORDER TO EQUALIZE THE LOAD OVER THE NETWORK. IDENTIFICATION WAS TREATED AS A SYSTEM-WIDE FUNCTION, SO THAT A TRACK ONCE IDENTIFIED BY ANY RADAR DID NOT HAVE TO BE RE-IDENTIFIED UNLESS THE TRACK LEFT THE COVERAGE OF THE ENTIRE NETWORK.

THE INTERFACING OF THE OPERATOR AND THE AUTOMATED NETWORK WAS EXAMINED IN DETAIL. PROCEDURES FOR EXPRESSING OPERATOR PREFERENCES CONVENIENTLY AND NATURALLY WERE DEVELOPED. THE ISSUE OF CONTENTION AMONG AN OPERATOR AT A CONTROL CENTER, AN OPERATOR AT AN INDIVIDUAL RADAR, AND THE AUTOMATED SYSTEM WAS EXAMINED.

WE LOOKED AT THE DIFFERENT TYPES OF CONTROL PARAMETERS WHICH ARE APPROPRIATE FOR THE CONTROL OF INDIVIDUAL RADARS AND FOR COMMUNICATION BETWEEN RADARS.

WE TREATED THE ISSUE OF WHERE INFORMATION SHOULD BE STORED, WHERE IT SHOULD BE SENT, WHEN IT SHOULD BE SENT, AND WHERE IT SHOULD BE COMBINED.

THE ISSUE OF CONTROL SYSTEM DESIGN TO INSURE GRACEFUL DEGRADATION WAS EXAMINED IN DETAIL. AUTOMATIC PROCEDURES FOR ENSURING APPROPRIATE NETWORK RESPONSE TO THE LOSS OF A RADAR WERE DEVELOPED, AND OUR CONTROL SYSTEM ALSO PROVIDES AUTOMATIC GRACEFUL ENHANCEMENT OF THE NETWORK FUNCTIONS WHEN RADARS COME BACK INTO THE SYSTEM.

IN ORDER TO CALCULATE THE RESPONSE OF THE NETWORK WE DEVELOPED MEASURES OF EFFECTIVENESS AS AN INTEGRAL PART OF OUR METHODOLOGY.

PERHAPS MOST IMPORTANTLY, WE FOUND THAT IN ORDER TO HAVE A LOOSELY-COUPLED, INTELLIGENT RADAR NETWORK, IT IS NECESSARY TO HAVE INTELLIGENCE BUILT INTO THE INDIVIDUAL RADAR NODES. THIS IS ESPECIALLY IMPORTANT IF THE GOAL OF MINIMUM COMMUNICATIONS IMPACT IS TO BE REALIZED. THEREFORE, WE DESIGNED IN GREAT DETAIL, THE CONTROL STRUCTURE THAT WOULD BE NECESSARY WITHIN AN INDIVIDUAL RADAR SITE.

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CURRENT ACTIVITY CLASSES OF SCHEDULER

- SEARCH
- TRACK INITIATION
- TRACK MAINTENANCE
- IDENTIFICATION
- TRACK DROP

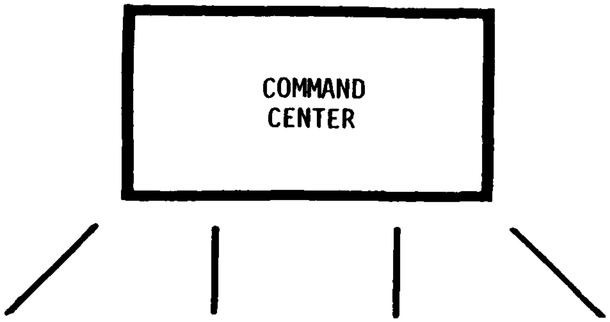
CONTROL SYSTEM ARCHITECTURE

THIS SLIDE ILLUSTRATES THE BASIC ARCHITECTURE FOR THE CONTROL SYSTEM. COMMUNICATION PROCESSORS AND OTHER PROCESSING ACTIVITIES NOT DIRECTLY RELATED TO THE CONTROL ARCHITECTURE ARE NOT SHOWN. THE COMMAND CENTER IS THE UPPER LEVEL CONTROL FOR THE SYSTEM. ITS FUNCTION, IN ESSENCE, IS TO CONTROL THOSE ACTIVITIES THAT REQUIRE DECISIONS AFFECTING MORE THAN ONE RADAR. IN OUR SCHEME, THE COMMAND CENTER SHOULD NOT NECESSARILY BE ASSOCIATED WITH ANY PARTICULAR ELEMENT OF OUR EXISTING TACTICAL AIR CONTROL SYSTEM (TACS). IT MAY BE LOCATED AT ANY RADAR NODE OR AT AN INDEPENDENT SITE, OR MAY EVEN BE MOVED DYNAMICALLY FROM SITE TO SITE. SYSTEM OPERATORS, HOWEVER, ARE ASSUMED TO BE LOCATED AT THE COMMAND CENTER.

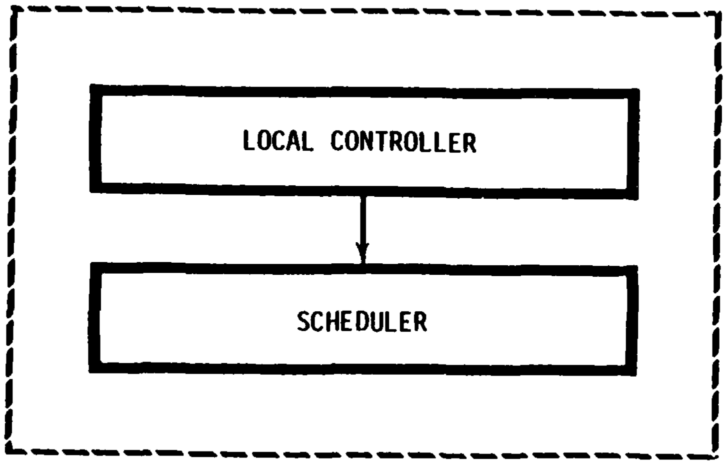
THE DOTTED LINE ENCLOSES THE TWO ELEMENTS WHICH COMPRISE EACH INDIVIDUAL RADAR SITE. THESE ARE THE LOCAL CONTROLLER AND THE SCHEDULER. THE SCHEDULER ON A DYNAMIC BASIS SELECTS FROM A LARGE NUMBER OF CANDIDATE ACTIVITIES THE ONE PARTICULAR ACTIVITY THAT THE RADAR WILL DO NEXT. ACTIVITIES ARE DRAWN FROM VARIOUS CLASSES SUCH AS: SEARCH, TRACK OR IDENTIFICATION. MATHEMATICALLY, THE SCHEDULER WORKS SIMPLY BY SELECTING THE MOST VALUABLE ACTIVITY AT EACH DECISION POINT AND ACTIVATING IT. THE VALUE OF EACH ACTIVITY IS DETERMINED BY THE USE OF VALUE-FUNCTIONS, THE BASIS OF OUR METHODOLOGY, WHICH UNFORTUNATELY I CANNOT COVER IN THIS PRESENTATION. I WILL BE GLAD TO MEET LATER WITH ANY OF YOU WHO WOULD LIKE TO KNOW THE DETAILS OF OUR VALUE FUNCTIONS.

THE LOCAL CONTROLLER HAS TWO PRINCIPLE FUNCTIONS. THE FIRST IS THE SELECTION OF CANDIDATE ACTIVITES FOR INCLUSION IN OR DELETION FROM THE ACTIVITY SETS OF THE SCHEDULER. THE SECOND FUNCTION IS TO DYNAMICALLY ADJUST THE CONTROL PARAMETERS OF THE SCHEDULER IN RESPONSE TO CHANGES IN THE ENVIRONMENT OR TO INITIATIVES FROM THE COMMAND CENTER.

CONTROL SYSTEM ARCHITECTURE



SETS SYSTEM OBJECTIVES, OBSERVES UNFOLDING AIR BATTLE, MODIFIES OBJECTIVES TO CORRESPOND TO CHANGING CONDITIONS, AND TRANSMITS OBJECTIVES TO INDIVIDUAL RADARS.



DETERMINE ACTIVITIES TO CONSIDER AS CANDIDATES FOR SCHEDULING AND ADJUSTS CONTROL PARAMETERS TO MEET SYSTEM OBJECTIVES.

SELECT ACTIVITIES TO OPTIMIZE SCHEDULE SUBJECT TO CONSTRAINTS ON RADAR.

CURRENT ACTIVITY CLASSES OF SCHEDULER

AT THE PRESENT TIME, THERE ARE FIVE ACTIVITY CLASSES FROM WHICH THE SCHEDULER CAN SELECT ACTIVITIES AS SHOWN ON THIS SLIDE. WITHIN SEARCH, EACH SECTOR IS SEPARATELY SCHEDULED; AND WITHIN THE TRACK CLASS, EACH TRACK IS SEPARATELY SCHEDULED. EVERY POSSIBLE ACTIVITY, REGARDLESS OF CLASS IS CONSIDERED FOR SCHEDULING AT EVERY DECISION POINT.

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MAJOR AREAS ADDRESSED

- NETWORK SEARCH, TRACK, IDENTIFICATION
- OPERATOR INTERFACE
- CONTROL PARAMETERS
- COMMUNICATION
- INFORMATION MANAGEMENT
- SURVIVABILITY
- MEASURES OF EFFECTIVENESS
- INDIVIDUAL RADAR CONTROL

FUNCTIONS OF LOCAL CONTROLLER

THE TWO PRINCIPLE FUNCTIONS OF THE LOCAL CONTROLLER ARE EXPANDED ON THIS SLIDE. IT IS THE ABILITY OF THE LOCAL CONTROLLER TO SELECT WHICH ACTIVITIES ARE TO BE CONSIDERED IN THE SCHEDULE BASED UPON THE DYNAMIC ENVIRONMENT OR DIRECTIVES OF THE COMMAND CENTER WHICH MAKES EACH RADAR NODE AN INTELLIGENT DECISION ENTITY.

ALSO, EACH RADAR SITE HAS A LOCAL OPERATOR WHO CAN OVERRIDE THE AUTOMATIC FUNCTIONS OF THE LOCAL CONTROLLER AS NECESSARY TO INSURE THAT THE SYSTEM IS RESPONSIVE TO HIS PREFERENCES.

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FUNCTIONS OF LOCAL CONTROLLER

- SELECTS ACTIVITIES FOR INCLUSION IN SCHEDULER CANDIDATE SET
- SELECTS ACTIVITIES FOR REMOVAL FROM SCHEDULER CANDIDATE SET
- ADJUSTS PARAMETERS IN SCHEDULER'S VALUE FUNCTIONS
- RESPONDS TO DIRECTIONS FROM COMMAND CENTER

FUNCTIONS OF COMMAND CENTER

THE FUNCTIONS OF THE COMMAND CENTER ARE SHOWN ON THIS SLIDE. THE COMMAND CENTER, AS THE NAME IMPLIES, PROVIDES DIRECTION FOR THE NETWORK. SYSTEM OPERATORS ARE LOCATED AT THE COMMAND CENTER, WHERE THEY CAN OVERRIDE EVERY AUTOMATIC FUNCTION AND LOCAL OPERATOR IN THE SYSTEM.

OUR TREATMENT OF NETWORK SEARCH AND TRACK FOLLOWS QUITE NATURALLY ONCE INTELLIGENCE HAS BEEN BUILT INTO THE LOCAL DECISION NODES. ESSENTIALLY, THE ASSIGNMENT OF RESPONSIBILITY TO EACH RADAR VARIES SUCH THAT THE SYSTEM LOAD TENDS TO BE EVENLY DISTRIBUTED OVER THE INDIVIDUAL RADARS.

THE NETWORK EMPLOYS THE CONCEPT OF SYSTEM AND LOCAL TRACKS, IN WHICH EACH RADAR MAINTAINS ITS OWN LOCAL TRACKS AND THE COMMAND CENTER MAINTAINS SYSTEM TRACKS, WHICH ARE COMPOSITES OF THE LOCAL TRACKS.

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FUNCTIONS OF COMMAND CENTER

- CONTROL OF NETWORK ACTIVITIES THAT REQUIRE MORE THAN ONE RADAR
- CAN BE LOCATED AT INDEPENDENT SITE OR AT ONE OF THE RADAR SITES
- LOCATION OF SYSTEM OPERATORS WHO SET NETWORK OBJECTIVES AND WHO CAN OVERRIDE AUTOMATIC OPERATION
- OBSERVES AND RESPONDS TO DYNAMICALLY CHANGING ENVIRONMENT
- MODIFIES OBJECTIVES OF LOCAL CONTROLLERS TO ACHIEVE NETWORK GOALS

RNET-OPERATOR'S STATION

IN THE SHORT TIME REMAINING, I WILL TURN TO A DEMONSTRATION OF A FEW RESULTS WHICH WE HAVE OBTAINED USING OUR NETTED RADAR SIMULATION, RNET. I HAVE CHOSEN THREE SIMPLE CASES WHICH WILL ILLUSTRATE THE BEHAVIOR OF THE CONTROL SYSTEM IN RNET.

THE OPERATOR'S STATION IS DEPICTED ON THIS SLIDE. WE HAVE A TERMINAL, IN THE CENTER, FOR COMMUNICATING WITH THE COMPUTER. ON THE RIGHT IS A TEKTRONIX GRAPHICS DISPLAY WHICH ALLOWS THE OPERATOR TO VIEW ANY SCENARIO, AT ANY TIME, IN GREAT DETAIL. ON THE LEFT THERE IS A TEKTRONIX HARD COPY UNIT FOR PERMANENTLY RECORDING ANY OF THE GRAPHICS DISPLAYS.

THE COMMAND SCREEN WHICH COMES UP ON THE OPERATOR'S TERMINAL IS THE HEART OF THE INTERACTIVE SYSTEM.

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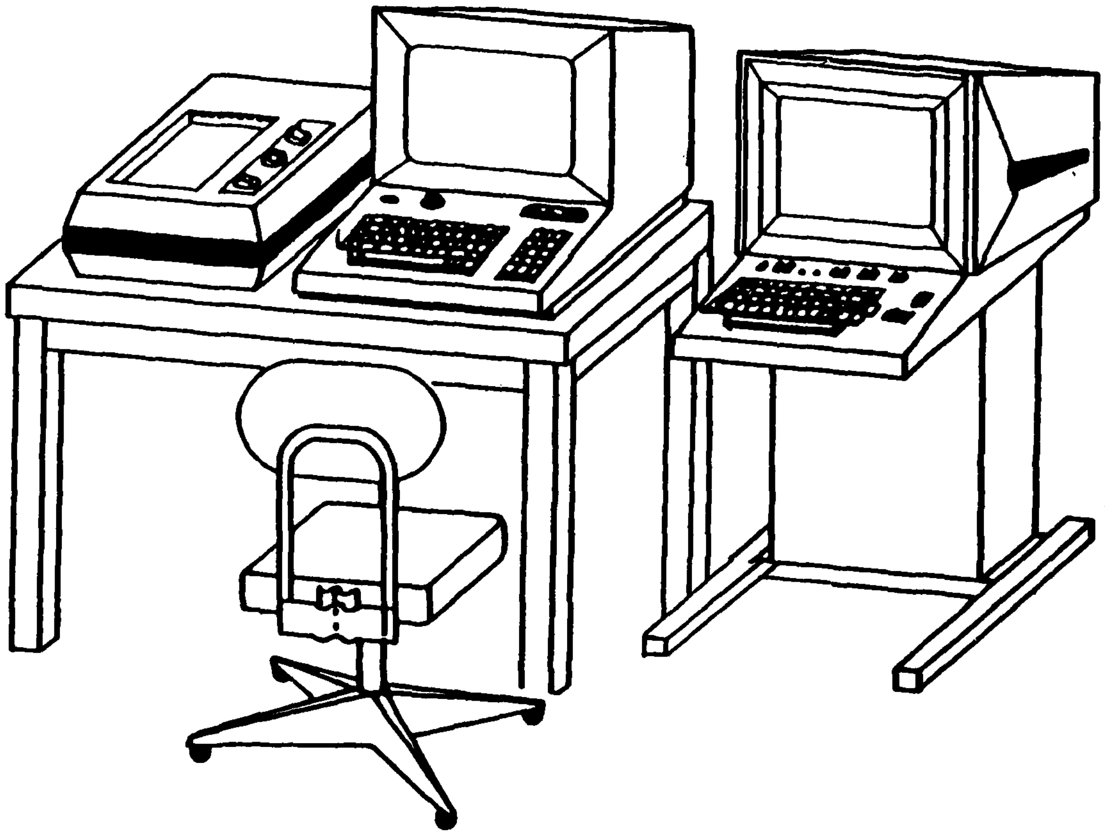
RNET-OPERATOR'S STATION



RNET

THE MAJOR FEATURES OF THE RNET SIMULATION ARE SHOWN HERE. WE HAVE USED THE SIMULATION TO DEVELOP THE RADAR AND RADAR NETWORK OF OUR CONTROL ARCHITECTURE.

IT IS HIGHLY INTERACTIVE WHICH PERMITS THE USER A WIDE VARIETY OF OPTIONS FOR ANALYZING SYSTEM PERFORMANCE.

THE GRAPHICS DISPLAYS PROVIDE A VISUAL AID IN THE ANALYSIS.

THE STRUCTURE OF RNET ALLOWS EXAMINATION OF SCENARIOS WHICH ARE OF THE COMPLEXITY AS USED IN THE SEEK SCREEN STUDY--SOMETHING THAT WE FEEL IS VERY IMPORTANT IN OBTAINING MEANINGFUL RESULTS.

IT IS VERY FAST RUNNING--ESSENTIALLY REAL TIME--AND EASILY MODIFIED TO ACCEPT DIFFERENT SCENARIOS OR NETWORK CONCEPTS.

DSA

RNET

- TEST-BED FOR DEVELOPING RADAR AND RADAR NETWORK AUTOMATIC CONTROL ALGORITHMS
- MONTE-CARLO INTELLIGENT RADAR NETWORK SIMULATION
- HIGHLY INTERACTIVE
- GRAPHICS DISPLAYS ALLOW USER TO VIEW SCENARIO DEVELOPMENT
- SCENARIO OF DETAIL OF "SEEK SCREEN"
- FAST RUNNING
- EASILY MODIFIED

INTERFACE TO RNET AS SEEN ON THE OPERATOR'S CONSOLE

THE COMMAND SCREEN PERMITS THE OPERATOR TO SELECT ANY ONE OF 20 POSSIBLE ACTIONS AT EACH TIME STEP IN THE SIMULATION. TIME DOES NOT ALLOW ME TO DESCRIBE WHAT ACTION WILL RESULT FROM EACH SELECTION, BUT I DO WANT TO MENTION FOUR.

IN THE LEFT COLUMN, NO. 18 PERMITS THE OPERATOR TO SELECT THE TIME OF THE NEXT STOP IN THE SIMULATION RUN WHEN HE MAY EXAMINE IN DETAIL WHAT IS TRANSPIRING. IN THE RIGHT COLUMN, NO. 21 PERMITS THE OPERATOR TO SELECT THE SCALING OF THE DISPLAY ON THE TEKTRONIX GRAPHICS SCREEN SO THAT HE CAN OBTAIN AS MUCH DETAIL AS NEEDED. ALSO ON THE RIGHT, NO. 23 CHECKPOINT, PROVIDES ONE OF THE MOST USEFUL FEATURES AS IT WILL ALLOW THE OPERATOR TO SAVE THE CURRENT STATE OF THE SIMULATION. THEN, AT SOME TIME LATER HE CAN RESET THE SIMULATION TO THE POINT SAVED, CHANGE CONDITIONS IF DESIRED AND RERUN THE SIMULATION TO OBSERVE THE RESULT OF HIS CHANGE. NO. 20, AT THE TOP OF THE RIGHT COLUMN PROVIDES A DETAILED TRACE OF THE ACTION OF THE SCHEDULER WITHIN ANY RADAR. I WOULD LIKE TO SHOW YOU AN EXAMPLE OF A RADAR TRACE.

DSA

INTERACTIVE INTERFACE TO RNET AS SEEN ON THE OPERATOR'S CONSOLE

RNET USER INTERFACE TIME = 2.500

SELECT ACTION - -

10.	AIRCRAFT	20.	RADAR TRACE
11.	MISSILES	21.	ZOOM
12.	RADARS	22.	DISPLAY LABELS
13.	RADAR SECTORS	23.	CHECKPOINT
14.	RADAR TRACKS	24.	PRINT OPTIONS
15.	NETWORK SEARCH	25.	CONTINUE
16.	NETWORK TRACK	26.	NON-STOP CONTINUE
17.	RADAR KILL	27.	HARD COPY
18.	SNAPSHOT	28.	HARD COPY NON-STOP
19.	AIRCRAFT TRACE	29.	ABORT

OPERATION OF THE RADAR SCHEDULER

THIS SLIDE SHOWS A PRINTOUT OF THE OPERATION OF THE SCHEDULER OF ONE RADAR FOR ABOUT 30 SECONDS. NOTE THAT THE SECTOR SEARCH AND TRACK UPDATE ACTIVITIES ARE INTERMINGLED IN NO PRESET ORDER. WE HAVE ONLY ONE TRACK IN THE SYSTEM AT THIS TIME. THE SCHEDULER IS SELECTING EACH ACTIVITY ON A DYNAMIC BASIS TO MAXIMIZE ITS VALUE FUNCTION AND NOT TO FOLLOW AN ARBITRARY SCHEDULE.

IN THE MIDDLE OF THE PRINTOUT YOU WILL SEE A NOTE THAT THE AIRCRAFT IS MANEUVERING AND THE SCHEDULER SHOULD ADJUST THE REVISIT TIME. THIS NOTE COMES FROM THE LOCAL CONTROLLER IN THE FORM OF A CHANGE TO THE VALUE CONTROL PARAMETERS. THE RESULT IS, AS YOU CAN SEE IN THE BOTTOM OF THE PRINTOUT, THAT THE SCHEDULER UPDATES THE TRACK MUCH MORE FREQUENTLY.

WE CAN SEE THIS CHANGE IN TRACK UPDATE RATE MORE VIVIDLY IF WE PLOT THE REVISTS ON A TIME SCALE.

DSA

OPERATION OF THE RADAR SCHEDULER FOR MANEUVERING AIRCRAFT

```
TRACK UPDATE: TRK    1 RANGE   23.74  SECTOR  2  TRUE ID 600
SEARCH:  SECTOR      9 TIME    4.642
SEARCH:  SECTOR      5 TIME    4.645
SEARCH:  SECTOR      1 TIME    4.648
SEARCH:  SECTOR     10 TIME    4.665
SEARCH:  SECTOR      6 TIME    4.683
SEARCH:  SECTOR     11 TIME    4.707
SEARCH:  SECTOR     10 TIME    4.725
SEARCH:  SECTOR      5 TIME    4.728
SEARCH:  SECTOR      1 TIME    4.731
SEARCH:  SECTOR      6 TIME    4.748
TRACK UPDATE: TRK    1 RANGE   25.30  SECTOR  2  TRUE ID 600
SEARCH:  SECTOR      4 TIME    4.750
SEARCH:  SECTOR      2 TIME    4.753
SEARCH:  SECTOR      3 TIME    4.755
SEARCH:  SECTOR     13 TIME    4.775
SEARCH:  SECTOR     10 TIME    4.793
SEARCH:  SECTOR      6 TIME    4.811
SEARCH:  SECTOR      5 TIME    4.813
SEARCH:  SECTOR      1 TIME    4.816
SEARCH:  SECTOR      7 TIME    4.841
TRACK UPDATE: TRK    1 RANGE   26.30  SECTOR  2  TRUE ID 600
AIRCRAFT MANEUVERING: ADJUST REVISIT TIME
SEARCH:  SECTOR     10 TIME    4.858
SEARCH:  SECTOR      8 TIME    4.881
SEARCH:  SECTOR      6 TIME    4.899
SEARCH:  SECTOR      4 TIME    4.901
SEARCH:  SECTOR      5 TIME    4.904
SEARCH:  SECTOR      2 TIME    4.906
SEARCH:  SECTOR      1 TIME    4.909
SEARCH:  SECTOR     10 TIME    4.926
SEARCH:  SECTOR      3 TIME    4.928
SEARCH:  SECTOR      9 TIME    4.953
TRACK UPDATE: TRK    1 RANGE   27.32  SECTOR  2  TRUE ID 600
SEARCH:  SECTOR      6 TIME    4.970
SEARCH:  SECTOR     15 TIME    4.995
SEARCH:  SECTOR     10 TIME    5.012
TRACK UPDATE: TRK    1 RANGE   27.32  SECTOR  2  TRUE ID 600
SEARCH:  SECTOR      5 TIME    5.015
SEARCH:  SECTOR      1 TIME    5.018
SEARCH:  SECTOR     14 TIME    5.036
SEARCH:  SECTOR      6 TIME    5.054
TRACK UPDATE: TRK    1 RANGE   27.32  SECTOR  2  TRUE ID 600
```

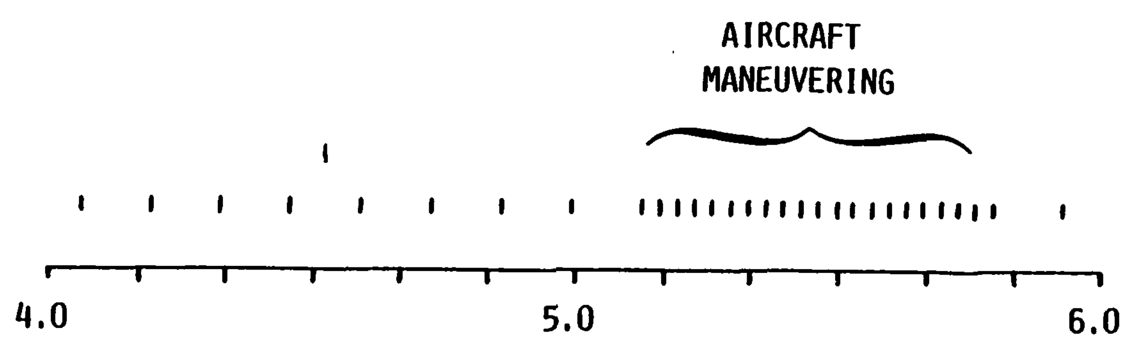
ADJUSTMENT OF TRACK REVIST TIME

HERE IS THE TIME PLOT FOR TWO MINUTES MARKING EACH TRACK UPDATE ACTIVITY. RECALL, THERE IS ONLY ONE TRACK. IT IS CLEAR THAT DURING THE FIRST MINUTE THE SCHEDULER UPDATED THE TRACK ABOUT ONCE EVERY 8 OR 9 SECONDS. WHEN THE AIRCRAFT MANEUVERS, THE UPDATE RATE INCREASES TO ABOUT ONCE EVERY 2 SECONDS UNTIL THE AIRCRAFT CEASES ITS MANEUVER.

THIS IS A SINGLE EXAMPLE OF THE INTELLIGENCE WHICH HAS BEEN BUILT INTO THE LOCAL RADAR NODES. I'LL TURN NOW TO A TWO RADAR NETWORK EXAMPLE

DSA

ADJUSTMENT OF TRACK REVISIT TIME FOR MANEUVERING AIRCRAFT



RADAR COVERAGE LIMITS, TWO RADARS

THE GEOMETERY OF A TWO RADAR CASE IS SHOWN ON THIS SLIDE. THE TWO RADARS ARE LOCATED ABOUT 45 NAUTICAL MILES APART. AIRCRAFT F6-0 WILL FLY THE COURSE AS SHOWN. THE COVERAGE LIMITS ILLUSTRATED ARE THOSE FOR AN AIRCRAFT AT 2000 FT., WHICH IS WHERE AIRCRAFT 6 IS FLYING. THE INPUT DATA HAS SPECIFIED THAT THE NETWORK IS TO TRACK THE AIRCRAFT AT AN ACCURACY OF 50 METERS. WE WISH TO OBSERVE HOW THE COMMAND CENTER--WHICH IS NOT SHOWN IN THE PICTURE--WILL ASSIGN RESPONSIBILITY, AND HOW THE RADARS WILL REACT TO THEIR ASSIGNMENTS.

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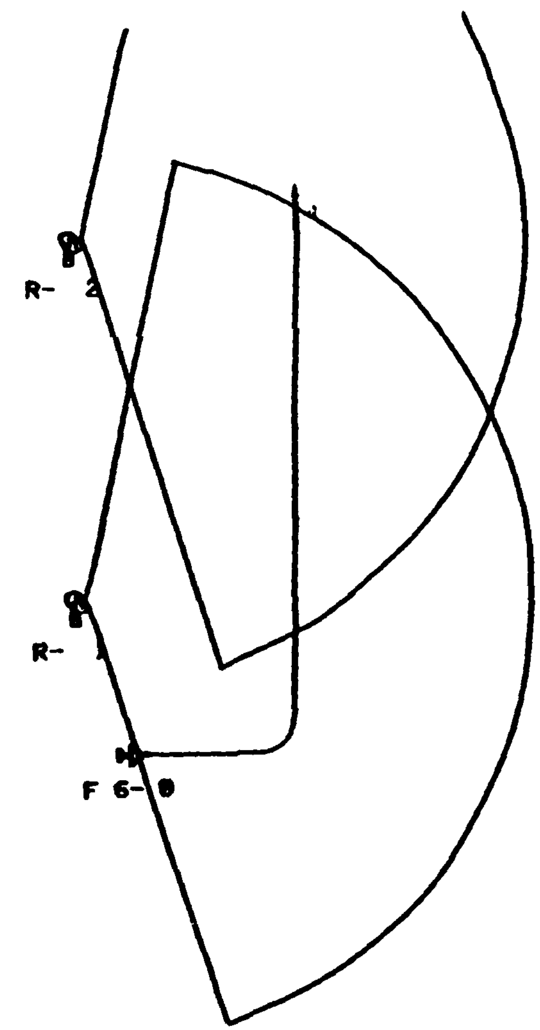
RADAR COVERAGE, LIMITS, TWO RADARS

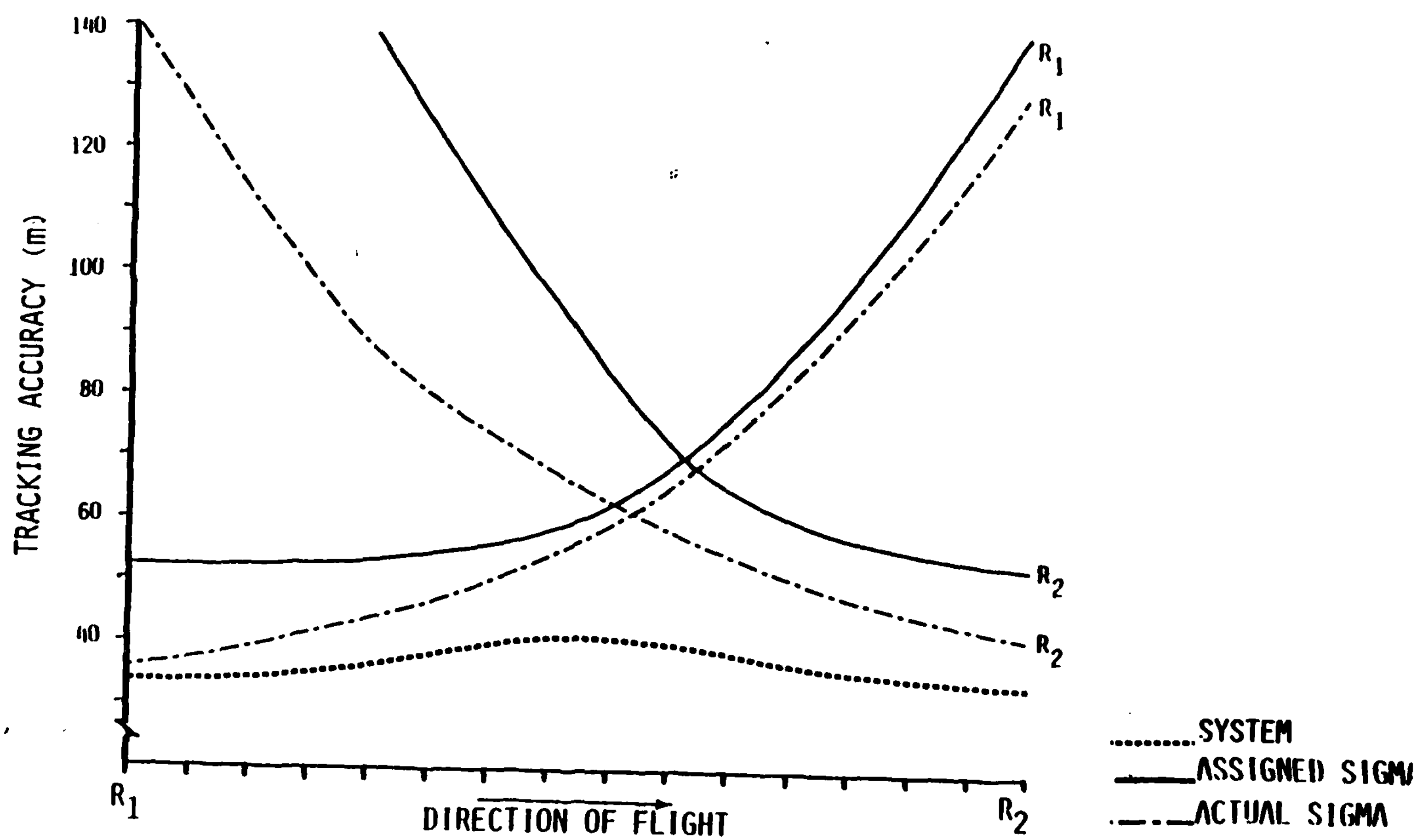


DIVISION OF RESPONSIBILITY FOR TRACKING ACCURACY

THIS PLOT SHOWS US HOW THE TWO RADARS COOPERATE TO TRACK AN AIRCRAFT TO THE DESIRED TRACKING ACCURACY. THE TWO RADARS ARE SHOWN AT THE BOTTOM OF THE PLOT. OUR AIRCRAFT F-6 FLIES FROM LEFT TO RIGHT. THE SOLID BLACK LINES SHOW THE ACCURACY WITH WHICH EACH RADAR MUST TRACK THE AIRCRAFT--THIS IS AUTOMATICALLY ASSIGNED BY THE COMMAND CENTER. THE DASHED BLACK LINES SHOW THE ACCURACY WITH WHICH THE RADAR IS ACTUALLY TRACKING AIRPLANE 6. NOTE THAT THE RADARS DO BETTER THAN ASKED. THIS IS A FEATURE OF OUR INTELLIGENT RADARS IN THAT THEY ALWAYS DO THEIR BEST--USUALLY BETTER THAN REQUIRED. THE RESULT OF THE COMBINED EFFORT IS A NETWORK TRACK MAINTAINED BY THE COMMAND CENTER WHICH KNOWS THE LOCATION OF THE AIRCRAFT WITH AN ACCURACY AS SHOWN BY THE BLUE LINE. SO, WE SEE THAT NETWORK TRACKING THE COMMAND CENTER IS CAPABLE OF DYNAMICALLY ASSIGNING RESPONSIBILITY AMONG THE VARIOUS RADARS IN ORDER TO ACHIEVE SYSTEM WIDE GOALS.

THIS PARTICULAR CASE ALSO PROVIDES A CHANCE TO EXAMINE THE GRACEFUL DEGRADATION FEATURE OF OUR SYSTEM. LET US SEE WHAT WOULD HAPPEN IF RADAR TWO WERE TO BECOME INOPERATIVE DURING THE RUN.

DIVISION OF RESPONSIBILITY FOR TRACKING ACCURACY BETWEEN TWO NETTED RADARS WITH EQUAL LOADS

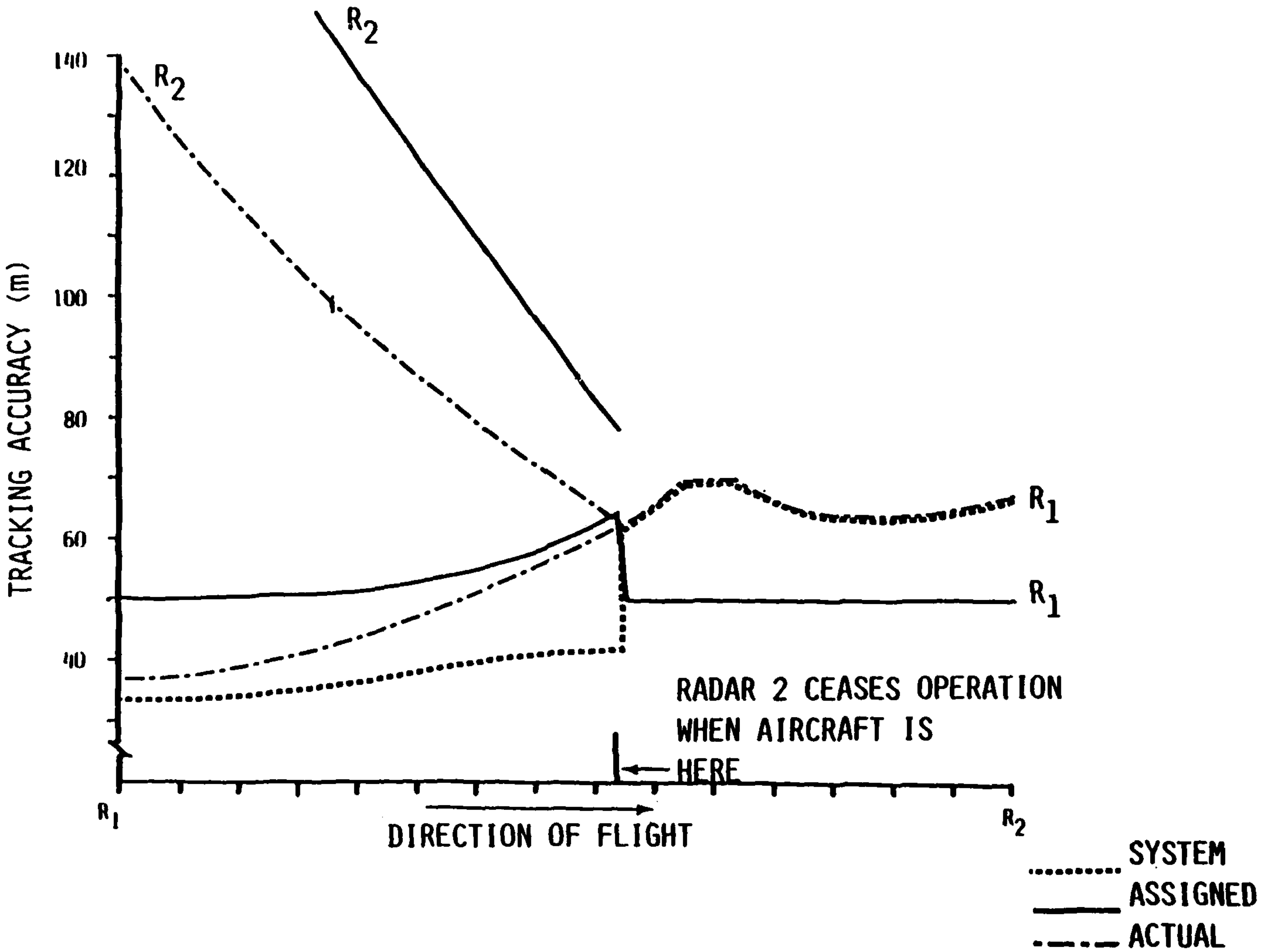


DIVISION OF RESPONSIBILITY WHEN ONE RADAR CEASES OPERATION

HERE WE SEE THE RESULTS OF THE NETWORK TRACKING FUNCTION WHEN RADAR TWO BECOMES INOPERATIVE AT ABOUT THE TIME OUR AIRCRAFT IS HALFWAY BETWEEN THE TWO RADARS. NOTE, THE COMMAND CENTER AUTOMATICALLY ADJUSTED THE ASSIGNED ACCURACY OF RADAR ONE TO ASSUME THE ENTIRE LOAD. NOTE, ALSO, RADAR ONE RESPONDED BY INCREASING ITS ACTUAL TRACKING ACCURACY TO MEET SYSTEM REQUIREMENTS. IN THIS PARTICULAR CASE, BECAUSE OF THE DISTANCE TO THE TARGET, RADAR ONE IS NOT ABLE TO ACHIEVE THE SYSTEM WIDE GOAL--IT DOES ITS BEST CONSISTENT WITH ALL OF ITS ASSIGNED RESPONSIBILITIES.

FINALLY, I'LL SHOW AN EXAMPLE OF A LARGER NETWORK SCENARIO.

DIVISION OF RESPONSIBILITY FOR TRACKING ACCURACY BETWEEN TWO NETTED RADARS WHEN ONE CEASES OPERATION



FIVE RADAR SCENARIO

THIS SLIDE IS MADE FROM THE TEKRONIX HARD COPY UNIT. WE HAVE FIVE RADARS NEAR THE CENTER OF THE PICTURE. A SEMI-CIRCLE OF AIRCRAFT BEHIND THE RADARS REPRESENT DEFENDING INTERCEPTORS. THE MASS TO THE RIGHT OF THE RADARS IS A LARGE FORMATION OF ATTACKING AIRCRAFT. THE AIRCRAFT IN THE UPPER LEFT REPRESENTS AN AWACS, AND THE ODD SHAPED OBJECTS POINTING TOWARD THE AWACS ARE THREE AIR-TO-AIR MISSILES WHICH HAVE BEEN FIRED AT THE AWACS. THESE MISSILES ARE OF VERY LOW CROSS SECTION, ARE TRAVELING AT ABOUT MACH 2, AND, ARE ABOUT 100 MILES FROM RADAR TWO. WE HAVE SPECIFIED THAT THE MISSILES ARE THE MOST IMPORTANT OBJECTS TO TRACK, AND THAT THEY BE TRACKED WITH AN ACCURACY OF 50 METERS. THIS TRACKING ACCURACY FOR THESE TARGETS IS ESSENTIALLY AN IMPOSSIBILITY FOR THE INDIVIDUAL RADARS. THIS SNAPSHOT LOOK IS TAKEN AFTER THE SCENARIO HAS BEEN DEVELOPING FOR 21 MINUTES.

I WANT TO SHOW YOU TWO SITUATIONS FOR THIS EXAMPLE. WE WILL LOOK AT ONE CASE WHERE THE RADARS ARE OPERATING INDEPENDENTLY AND AT A SECOND CASE WHERE THE RADARS ARE OPERATING WITH THE COMMAND CENTER DYNAMICALLY ASSIGNING AND REASSIGNING SEARCH AND TRACKING RESPONSIBILITIES. FIRST, HOWEVER, LET ME SHOW YOU HOW WE CAN USE THE INTERACTIVE GRAPHICS TO EXAMINE IN MORE DETAIL THE MASSIVE RAID WHICH IS JUST A 'BLOB' IN THIS PICTURE.

DSA

FIVE RADAR SCENARIO

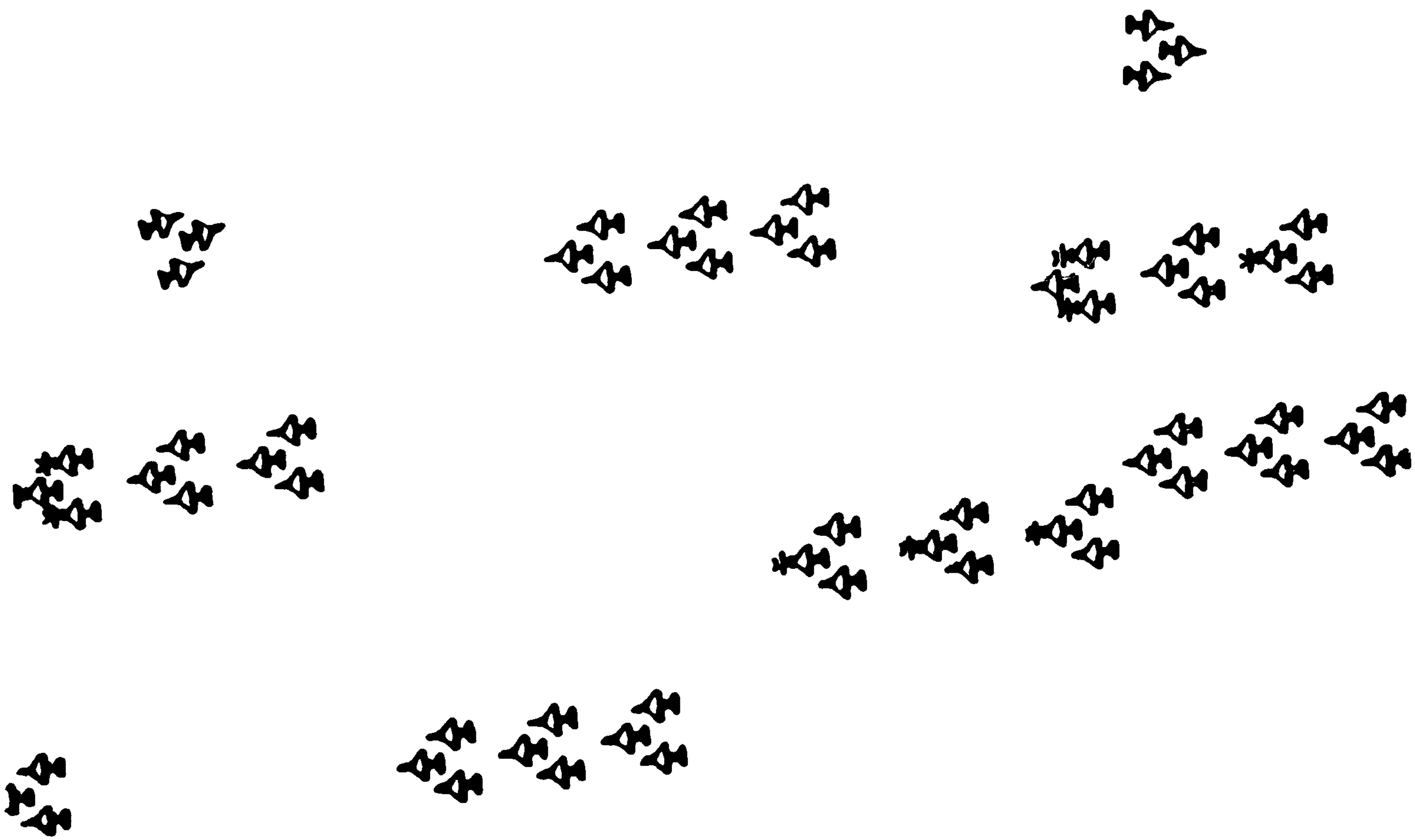
12X EXPANSION OF RAID

THIS IS AN EXPANSION BY A FACTOR OF ABOUT TWELVE OF THE RAID. NOTE THE AIRCRAFT FORMATIONS. THE 'STAR' ON THE FRONT OF SOME AIRCRAFT INDICATE THAT THEY ARE ACTIVELY JAMMING.

NOW BACK TO THE LOADING ON THE RADARS WHEN THEY ARE NOT NETTED.

DSA

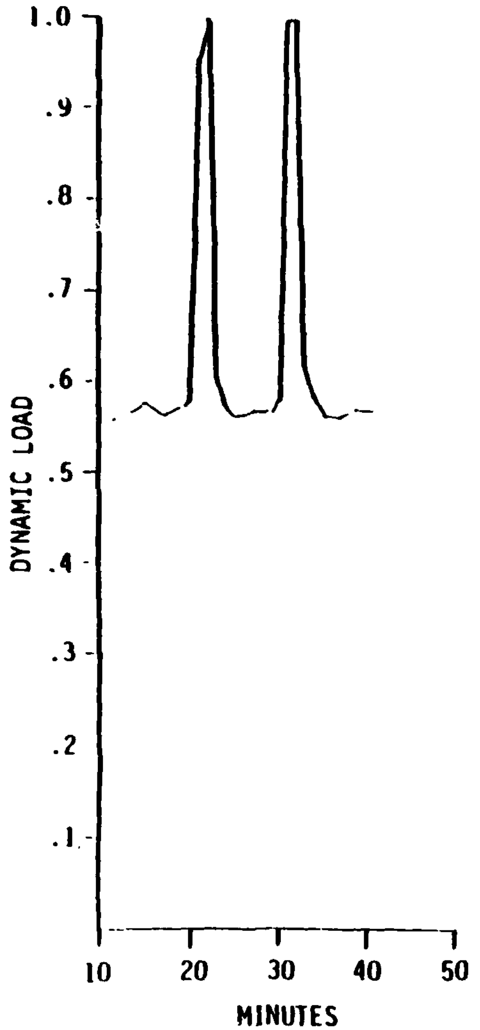
12 X EXPANSION OF RAID



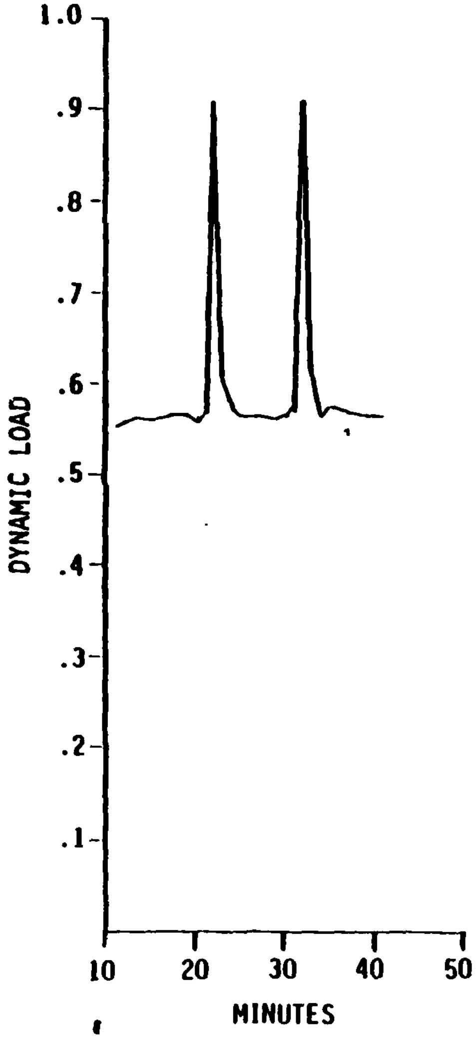
DYNAMIC LOADING--NO NETWORK

THIS PLOT SHOWS THE DYNAMIC LOADING OF THREE OF THE RADARS AS THE RAID PROGRESSES. THE SPIKES IN THE DYNAMIC LOAD CORRESPOND TO THE FLIGHT OF THE AIR-TO-AIR MISSILES AT ABOUT THE 20 MINUTE TIME, AND AGAIN 10 MINUTES LATER. IN THIS CASE, THE RADARS ARE ACTING INDEPENDENTLY, EACH TRYING TO ACHIEVE THE REQUIRED 50 METER TRACKING ACCURACY. FOR RADAR 2, THE TASK IS IMPOSSIBLE AND THE RADAR BECOMES OVERLOADED. FOR RADARS FIVE AND NINE, THE TASK IS NOT QUITE IMPOSSIBLE, BUT DOES CAUSE A SEVERE STRAIN. THE DIFFERENCE IN THE EFFECT ON THE RADARS IS DUE TO THE DISTANCE FROM THE RADARS TO THE MISSILES.

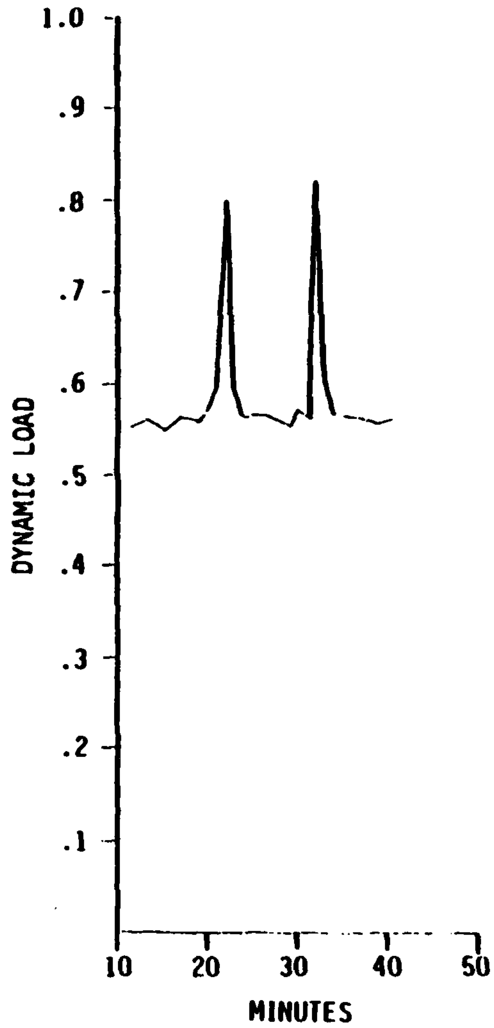
DSA DYNAMIC LOADING OF SELECTED RADARS



RADAR 2 FACE 2



RADAR 5 FACE 2



RADAR 9 FACE 2

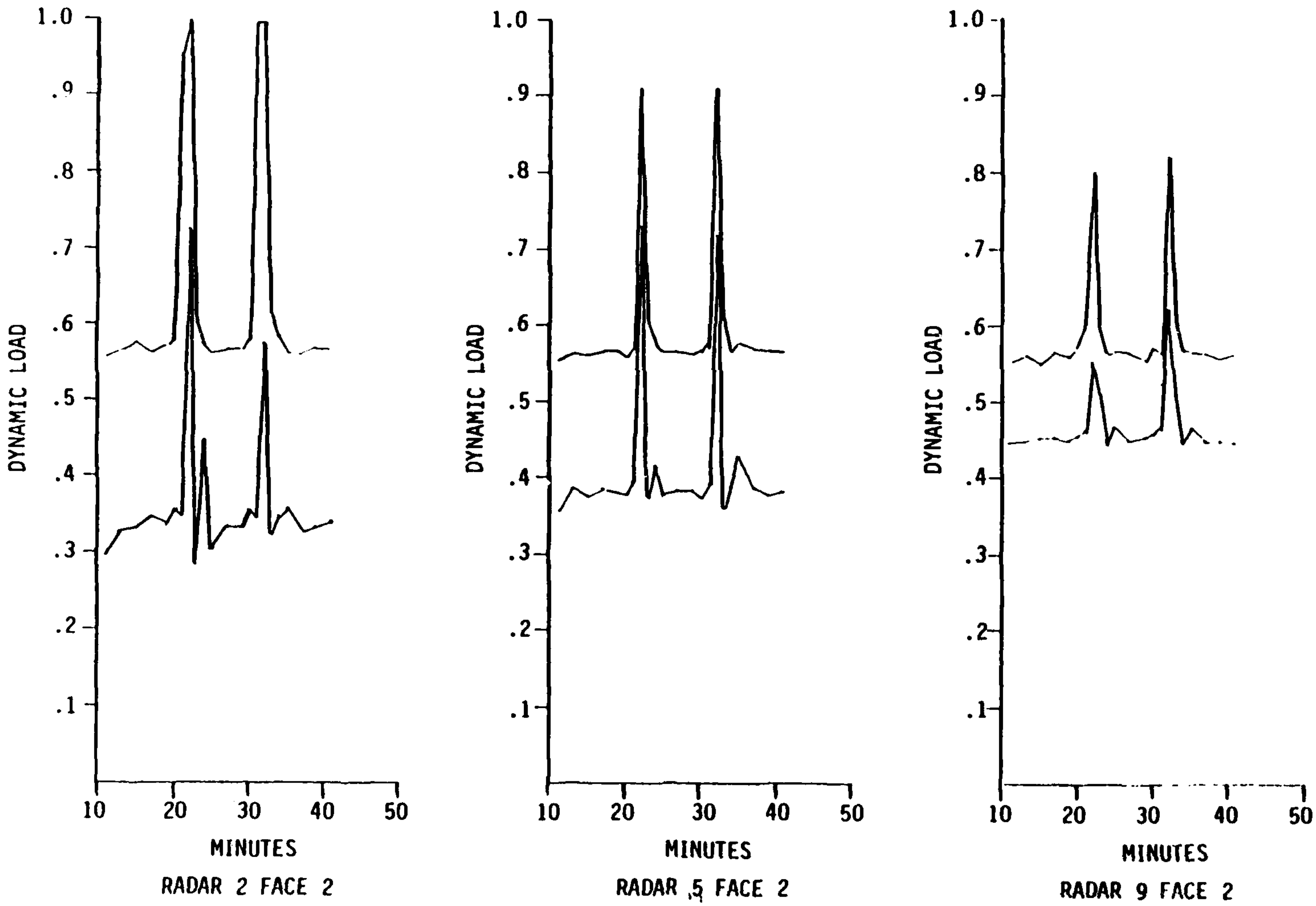
DYNAMIC LOADING--NETWORK ON

NOW LOOK AT WHAT HAPPENS WHEN WE LET THE COMMAND CENTER ACT AS AN INTELLIGENT NETWORK CONTROLLER. THE REQUIREMENT TO TRACK THE MISSILES REMAINS THE SAME, BUT NOW THE RADARS ARE COOPERATING AND AS A RESULT, NONE OF THEM BECOME OVERLOADED AND THE SYSTEM-WIDE GOAL IS MET. THIS IS RATHER DRAMATIC EVIDENCE OF THE VALUES TO BE GAINED BY AN INTERNETTING PROGRAM.

COMPARISON OF DYNAMIC LOADING OF RADARS WHEN NETTED AND NOT NETTED

DSA

(LOWER PLOT IN EACH INSTANCE IS FOR NETTED CASE)



SUMMARY

IN SUMMARY, THERE SHOULD NOT BE MUCH DOUBT REMAINING THAT NETTING IS THE NEXT SIGNIFICANT STEP TO BE TAKEN IN IMPROVING THE PERFORMANCE OF OUR DISTRIBUTED SENSOR SYSTEMS.

OUR CONTROL SYSTEM ARCHITECTURE DOES PROVIDE AN AUTOMATIC CONTROL THAT IS SUBJECT TO USER PRIORITIES.

RNET, THE NETTED RADAR SIMULATION IS A TOOL FOR THE STUDY OF MANY NETWORKING ISSUES.

DSA

SUMMARY

- FUTURE TACTICAL RADARS REQUIRE NETTING TO REALIZE FULL POTENTIAL OF CAPABILITIES
- VALUE-DRIVEN CONTROL SYSTEM ARCHITECTURE PROVIDES AUTOMATIC CONTROL THAT IS RESPONSIVE TO USER PRIORITIES
    - SURVIVABLE
    - MINIMIZES COMMUNICATIONS
    - EASILY EXTENDED
- RNET IS A USER ORIENTED, INTERACTIVE SIMULATION OF AN INTELLIGENT RADAR NETWORK
    - TEST-BED FOR DEVELOPING CONTROL ALGORITHMS
    - PRIORITY CONTROL COMMUNICATIONS NETWORK
    - STUDY TOOL FOR OPERATOR INTERFACE ISSUES

IMPLEMENTATION OF A LOCAL NETWORK

FOR TACTICAL SYSTEMS

SPERRY UNIVAC

RONALD W. FOSS

SPERRY UNIVAC

SERIAL DATA BUS ENVIRONMENT

CRITICAL REAL TIME DATA

SURVIVE MULTIPLE FAULTS WITH MINIMUM LOSS OF REAL TIME DATA

EQUIPMENTS FULLY QUALIFIED TO MIL-E-16400

FUNCTIONALLY TRANSPARENT TO EXISTING SUBSYSTEM APPLICATION SOFTWARE

SPERRY UNIVAC

LOCAL NETWORK FOR TACTICAL SYSTEMS

- REQUIREMENTS
  - RESPONSE TIME
  - THROUGHPUT
  - FAULT TOLERANCE
  - COMPATIBILITY
- DESIGN APPROACH
  - RESOURCE ALLOCATION
  - FAULT TOLERANCE
  - COMPATIBILITY
- PERFORMANCE
- SUMMARY
  - PRESENT STATUS
  - PLANS

CRITICAL SYSTEM RESPONSE TIME

- SENSOR UPDATES
  - TRACKING RADAR - 4.8 MSEC
  - ACOUSTIC SENSORS - 4.8 MSEC
  - TRACK BASE - 300+ TRACKS/SEC
- ATTITUDE UPDATES
  - TRACK PROCESSING - 1 MSEC
  - LASER TRACKING - 0.48 MSEC
- WEAPON CONTROL
  - AREA WEAPONS - 4.8 MSEC
  - CLOSE-IN WEAPONS - 1 MSEC
- NAVIGATION - 100 MSEC
- OTHER UPDATE INTERVALS - $\leq$ 1 SEC
- MULTIPLE DESTINATIONS FOR MOST MESSAGES

THROUGHPUT REQUIREMENTS

THROUGHPUT FUNDAMENTALLY DIFFERENT FROM NON-REAL TIME SYSTEMS

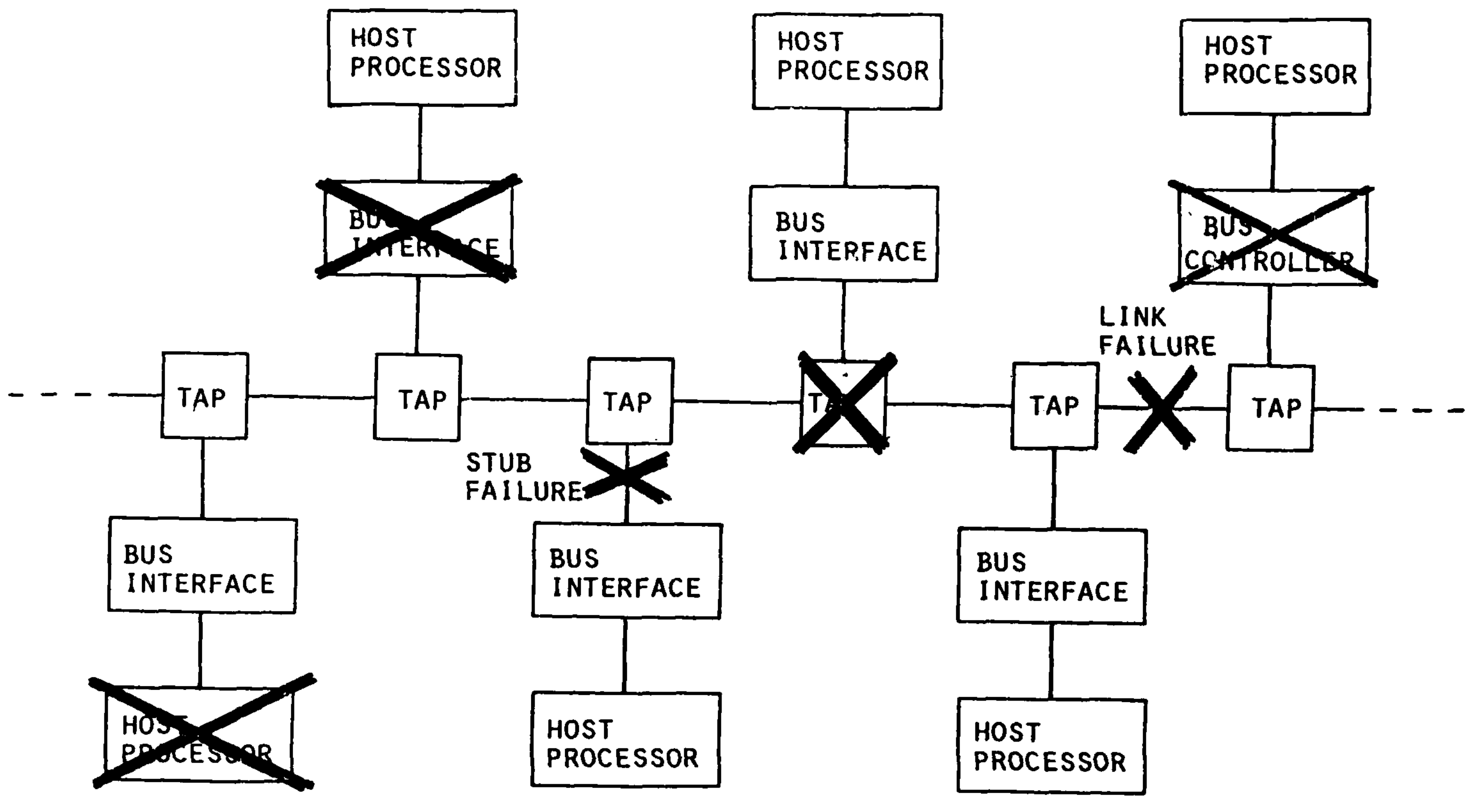
- JITTER CRITICAL TO TRACKING, AIMING AND NAVIGATION
- TRAFFIC GENERATORS ARE PREDOMINANTLY SYNCHRONOUS
- TRAFFIC GENERATORS CAN BE MUTUALLY SYNCHRONOUS

REQUIRED INFORMATION RATES 2 MBPS NOMINAL
8 MBPS PEAK

AVERAGE MESSAGE LENGTH 9.9 16 BIT WORDS

SUPPORT BOOT LOADS OF ALL HOST PROCESSORS

DATA BUS FAILURE MODES



- REQUIREMENTS
  - RESPONSE TIME
  - THROUGHPUT
  - FAULT TOLERANCE
  - COMPATIBILITY
- DESIGN APPROACH
  - RESOURCE ALLOCATION
  - FAULT TOLERANCE
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SUMMARY OF CHARACTERISTICS

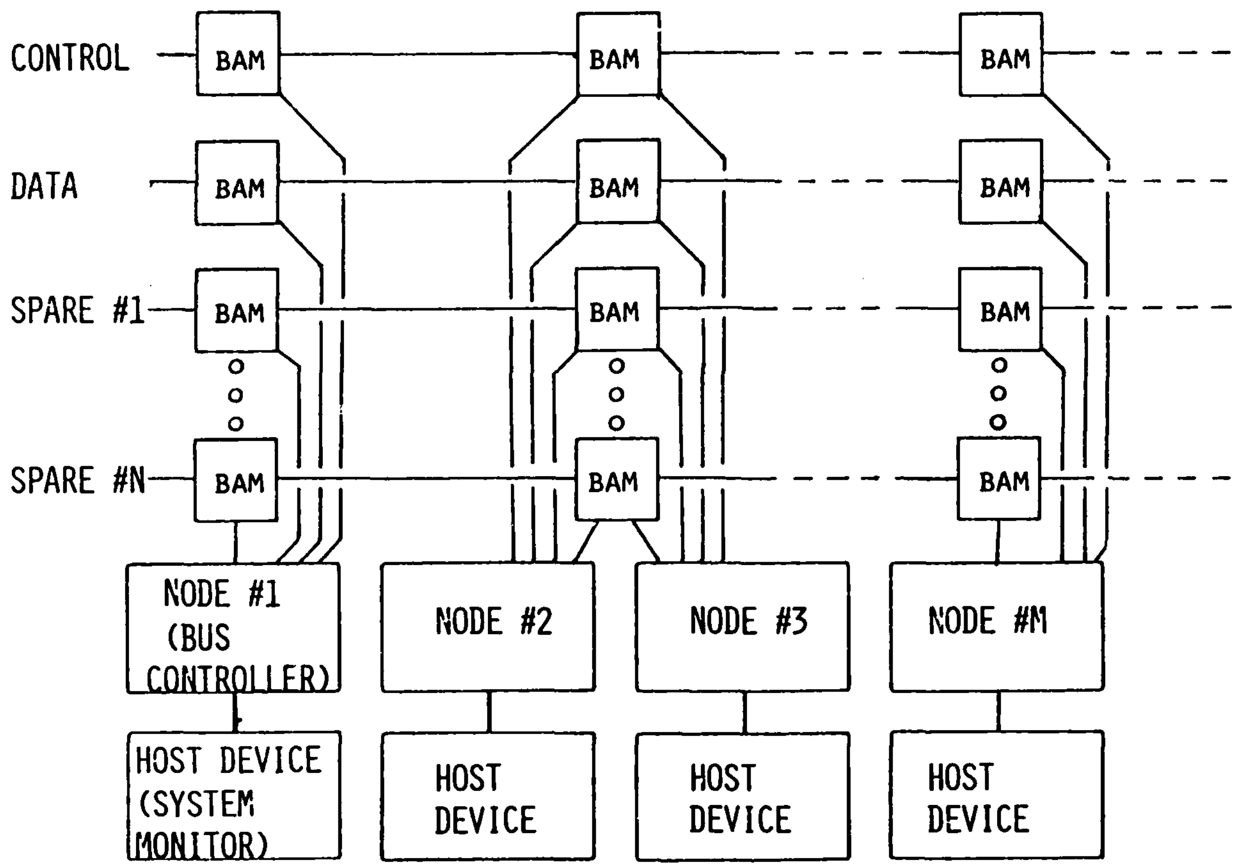
BUS TRANSMISSION SYSTEM

- SEPARATE DATA AND CONTROL CIRCUITS
- UP TO FOUR SPARE CHANNELS
- CHANNEL TRANSMISSIONS: 10 MHZ MANCHESTER
- 256 USERS OVER 300 METER BUS: 30 METER STUBS

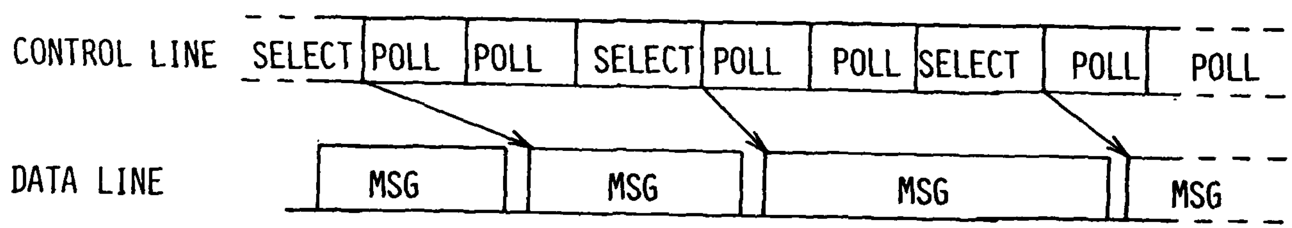
SERIAL DATA BUS SYSTEM

- POLLED BUS ARBITRATION DOES NOT INTERRUPT DATA FLOW
- POLL SEQUENCE PROGRAMMABLE IN REAL TIME
- DYNAMIC REASSIGNABLE BUS CONTROL
- MULTIPLE PRIORITY LEVELS
- BROADCAST & POINT-TO-POINT ADDRESSING
- MESSAGE FILTER BY DEVICE ADDRESS OR BY MESSAGE CONTENT
- 500 USEC ACCESS TIME
- VARIABLE MESSAGE LENGTH TO 127 - 32 BIT WORDS
- MESSAGE BUFFERING PERFORMED IN BUS INTERFACE NODE

SERIAL DATA BUS OPERATION



STEP	ACTIVITY
1.	USER TRANSFERS MESSAGE TO NODE OUTPUT BUFFER
2.	NODE REPLIES TO NEXT POLL WITH MESSAGE REQUEST WHICH CONTAINS PRIORITY FROM MESSAGE HEADER
3.	NODE WAITS FOR SELECT COMMAND FROM BUS CONTROLLER
4.	NODE TRANSMITS MESSAGE WHEN DATA CHANNEL IS QUIESCENT
5.	IF A MESSAGE BEING TRANSMITTED IS INTERRUPTED FOR A PRIORITY 0 MESSAGE THE NODE RESTARTS AT STEP 2.



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TWO LEVEL PRIORITY STRUCTURE PROVIDES BUS ACCESS FOR CRITICAL TRAFFIC

LEVEL I: POLL SEQUENCE

- UP TO 16 HIGH PRIORITY NODES
- UP TO 256 LOW PRIORITY NODES
- LOW PRIORITY NODE SUBSETS POLLED AFTER EACH HIGH PRIORITY POLL CYCLE

LEVEL II: MESSAGE QUEUEING AT EACH NODE

- 896 - 32 BIT WORD BUFFER FOR PRIORITY 1, 2, 3 MESSAGES
- SEPARATE BUFFER FOR A PRIORITY ZERO MESSAGE
- NODE TRANSMITS HIGHEST PRIORITY MESSAGE WHEN POLLED
- NODE ABORTS TRANSMISSION IN FAVOR OF A PRIORITY ZERO MESSAGE.
  ABORTED MESSAGE RETAINED IN XMIT QUEUE

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FAULT TOLERANCE WAS CRITICAL IN THE SERIAL DATA BUS DESIGN

FAILURE MODES	DESIGN FEATURE
BUS LINK	MULTIPLE PATHS, AUTOMATIC OUTAGE DETECTION
TAP, STUB	PASSIVE TAP WITH ACTIVE ISOLATION OF STUB
NODE	INTEGRAL TRANSMIT TIMEOUT TO AVOID CHATTERING SELECTIVE NODE DISABLE NODE RESPONSE TESTED EVERY 100 MSEC
HOST	PRE-PLANNED FALL-BACK PARTITIONING
BUS CONTROLLER	ANY NODE MAY BE CONFIGURED AS BACKUP CONTROLLER ALL CONTROLLER NODES MONITOR TRAFFIC FOR ERRORS - EACH ATTEMPTS RECOVERY IN PRE-PLANNED ORDER ACTIVE BUS CONTROLLER DEFERS TO CONTROL ACTIVITY ON NEW CHANNEL

CHANNEL MONITORING

- o ALL NODES CYCLICALLY SCAN ALL CHANNELS (500 USEC/CHANNEL)
- o A CONTROL CHANNEL CHANGE INITIATED BY THE USER CAUSES THE BUS CONTROLLER TO
  - CHANGE TO THE NEW CONTROL CHANNEL
  - TRANSMIT A CHANNEL CONTROL COMMAND EVERY 100 USEC FOR 5 MSEC
- o ANY NODE WHICH RECEIVES 3 CORRECTLY CODED CHANNEL CONTROL COMMANDS WITH NO INTERVENING ERRORS SWITCHES TO THE NEW CHANNEL
- o A BUS CONTROLLER WHICH OBSERVES THIS SEQUENCE WILL DROP THE BUS CONTROLLER MODE

SYSTEM COMPATIBILITY ACHIEVED BY PERFORMING BUS OPERATIONS IN THE NODE

NODE COMMUNICATES WITH HOST PROCESSOR VIA STANDARD I/O CHANNEL

NODE PERFORMS ALL BUS FUNCTIONS

- MESSAGE QUEUEING
- TRANSMISSION CONTROL
- RECEPTION CONTROL
- MESSAGE ACKNOWLEDGEMENT
- BUS ERROR MONITORING

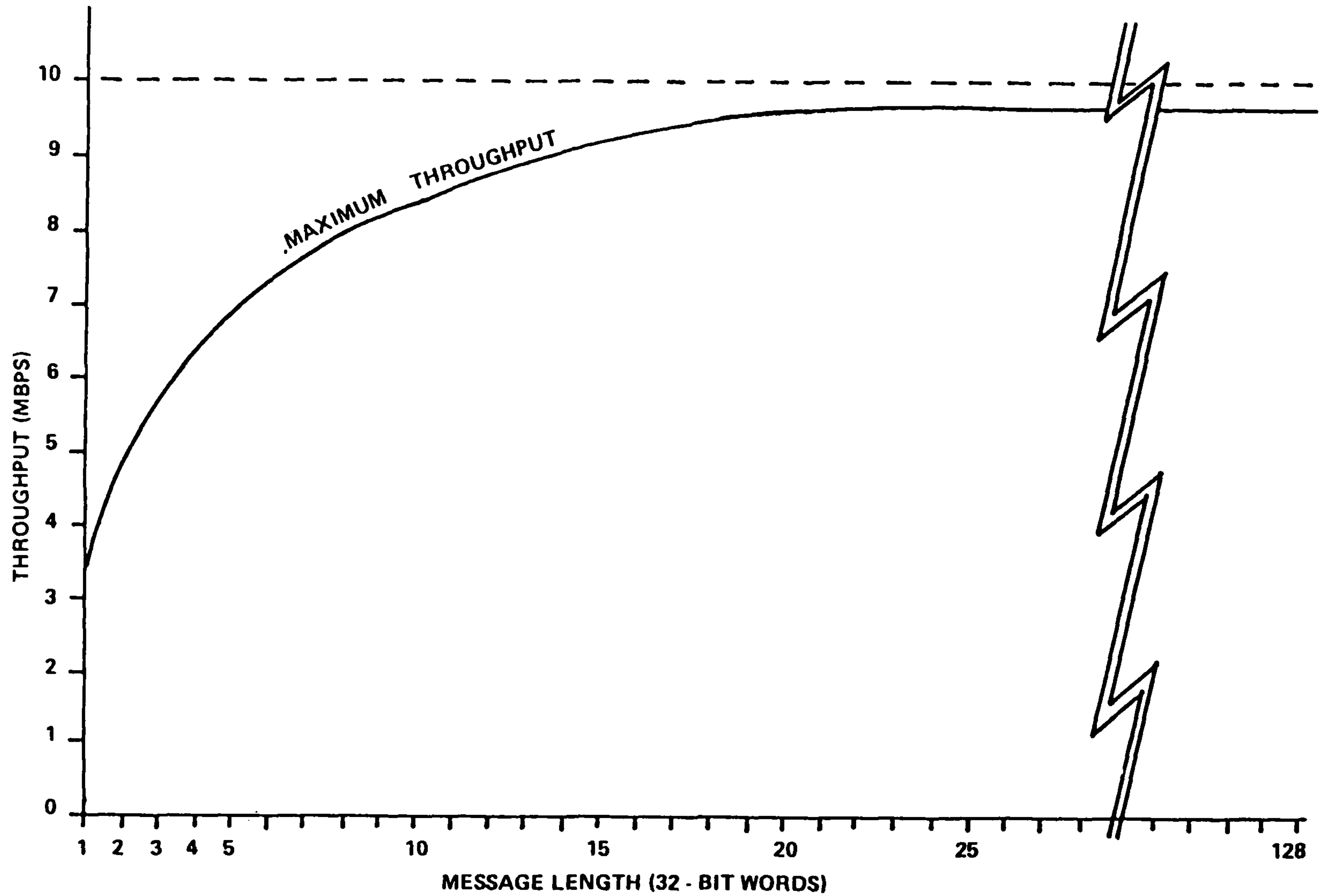
BUS CONTROLLER NODE PERFORMS ALL POLLING

NODE PROVIDES STATUS REPORTS TO HOST UPON SYSTEM RECONFIGURATION

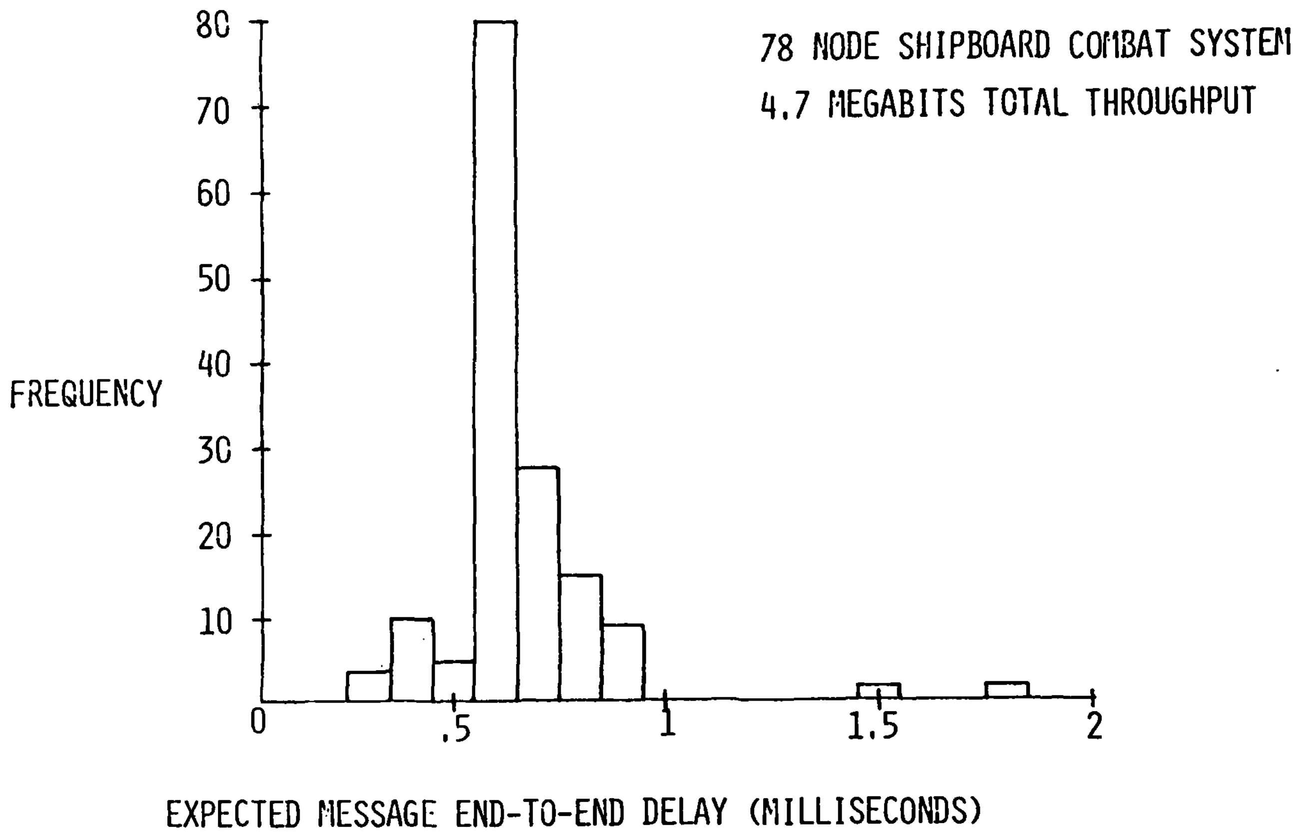
BUS CONTROLLER HOST CONTAINS STANDARD SYSTEM RECONFIGURATION TASK

- REQUIREMENTS
  - RESPONSE TIME
  - THROUGHPUT
  - FAULT TOLERANCE
  - COMPATIBILITY
- DESIGN APPROACH
  - RESOURCE ALLOCATION
  - FAULT TOLERANCE
  - COMPATIBILITY
- PERFORMANCE
- SUMMARY
  - PRESENT STATUS
  - PLANS

THROUGHPUT VS MESSAGE LENGTH



SPERRY UNIVAC MESSAGE END-TO-END DELAY HISTOGRAM



- REQUIREMENTS
  - RESPONSE TIME
  - THROUGHPUT
  - FAULT TOLERANCE
  - COMPATIBILITY
- DESIGN APPROACH
  - RESOURCE ALLOCATION
  - FAULT TOLERANCE
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- SUMMARY
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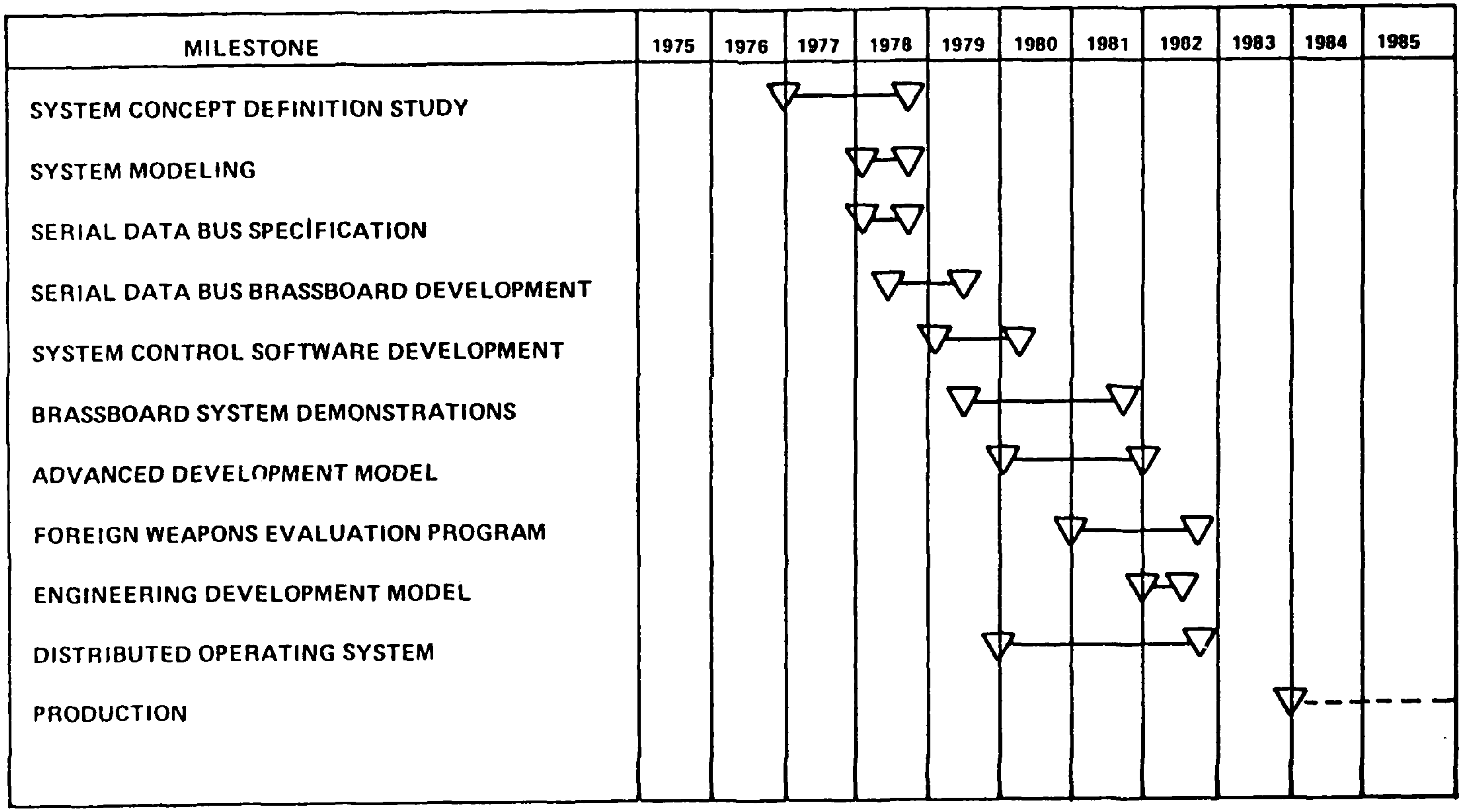
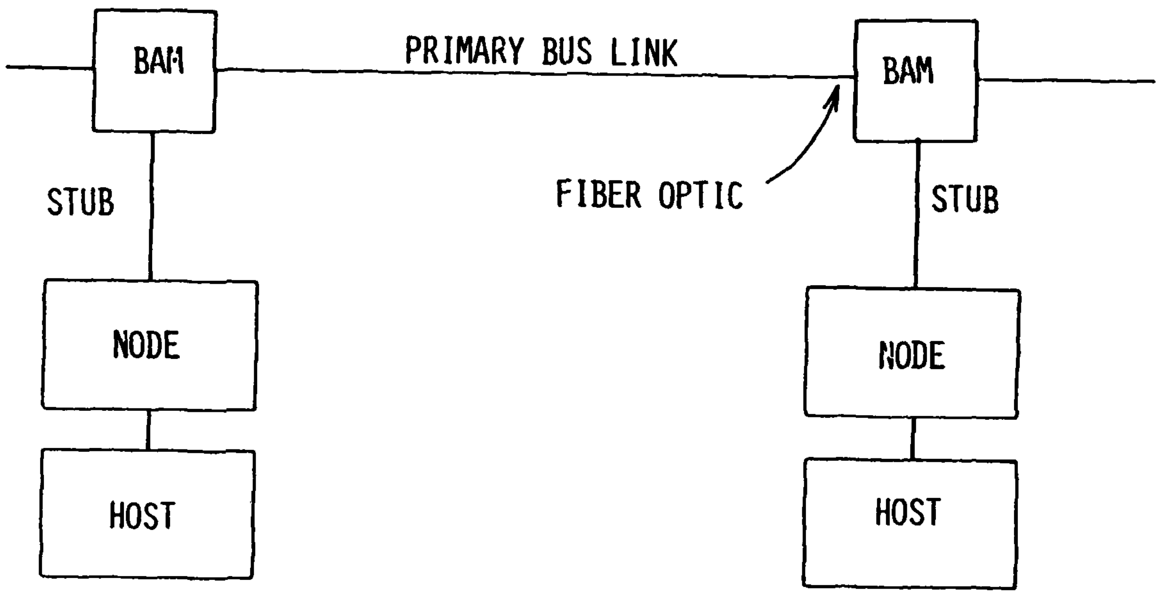
SYSTEM DEVELOPMENT STATUS



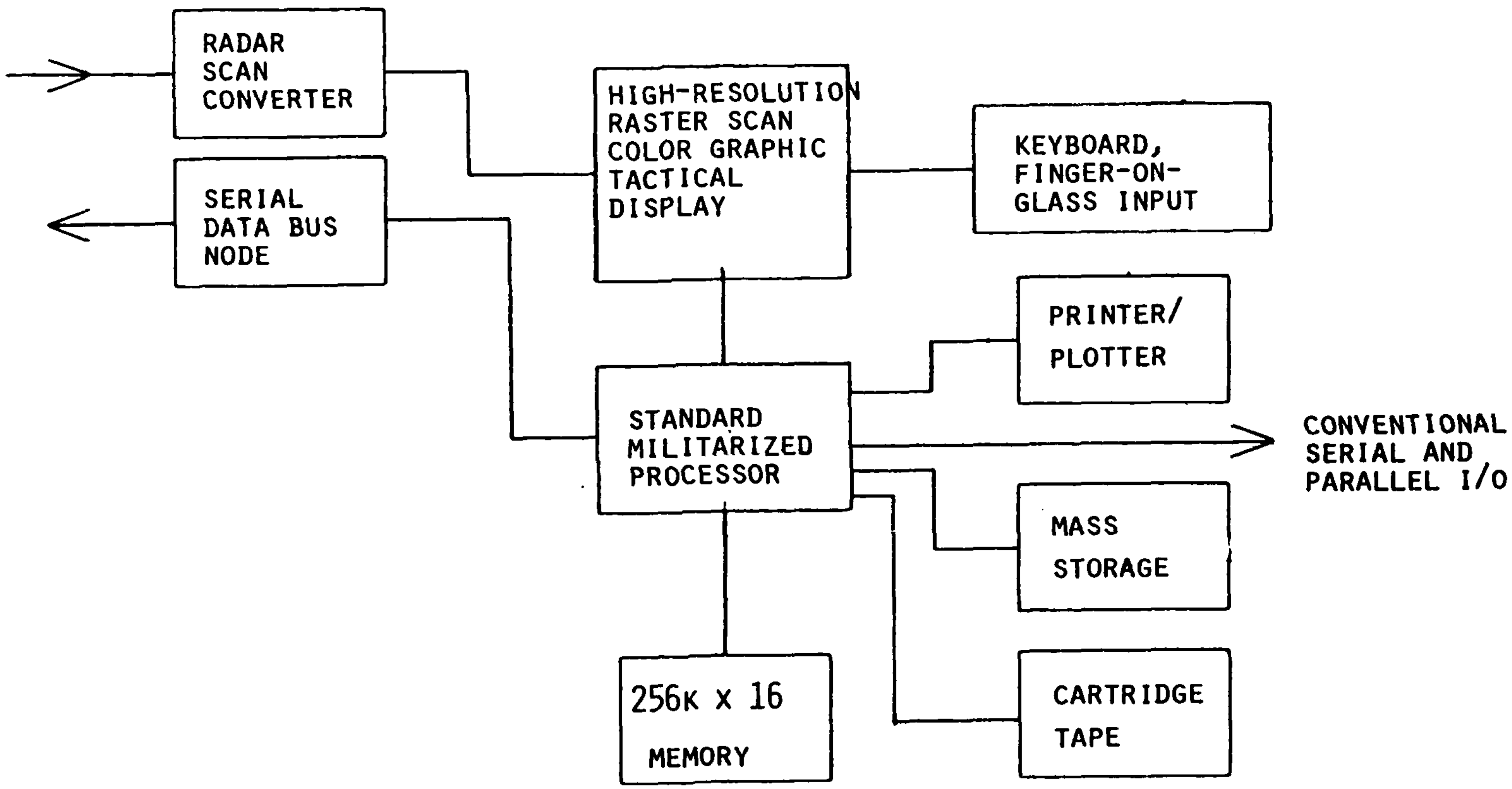
SPERRY UNIVAC THE SDB IS CONVERTIBLE TO FIBER OPTICS

FIBER OPTIC PRIMARY BUS LINK DEMONSTRATION SCHEDULED IN CY 82



SPERRY UNIVAC

THE MILITARIZED TACTICAL SYSTEM MODULE WITH INTEGRAL SDB NODE PROVIDES C^3I SYSTEM MODULARITY AT EACH OPERATORS STATION



A CONCEPTUAL
LOCAL AREA COMMUNICATIONS NETWORK
FOR
A DISTRIBUTED
MODULAR OPERATIONS CENTER

2053-1

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MODULAR OPERATIONS CENTER CONCEPT STUDY

ROME AIR DEVELOPMENT CENTER

2053-2

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MODULAR DISTRIBUTED C^3

2053-3

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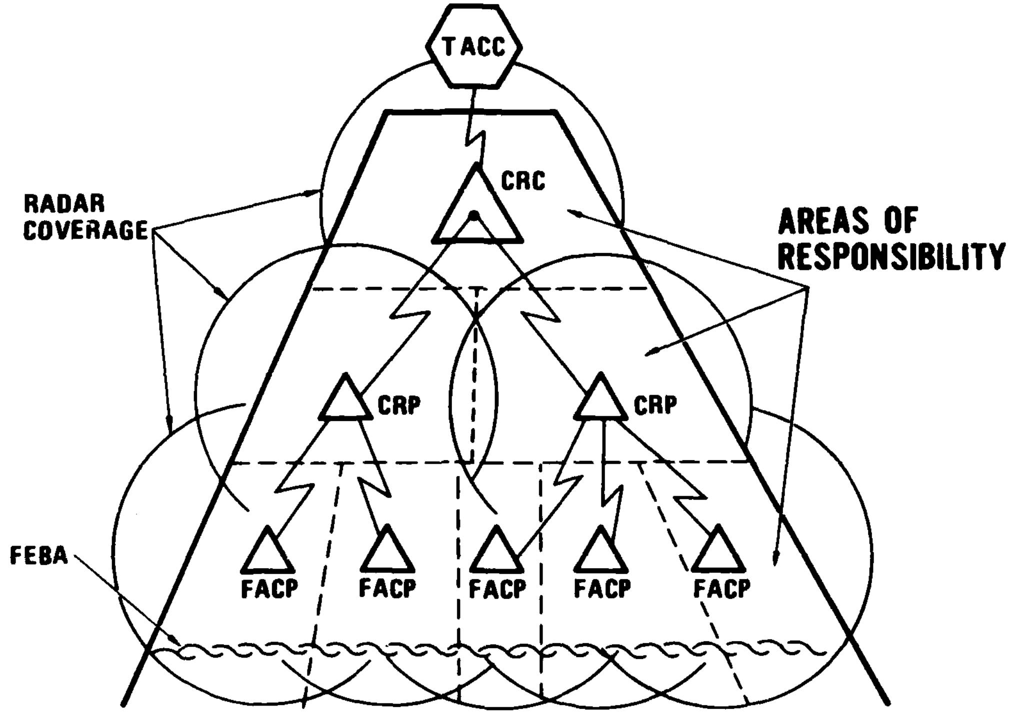
CURRENT EMPLOYMENT CONCEPT FOR SURVEILLANCE AND AIRSPACE CONTROL FUNCTION



2053-4

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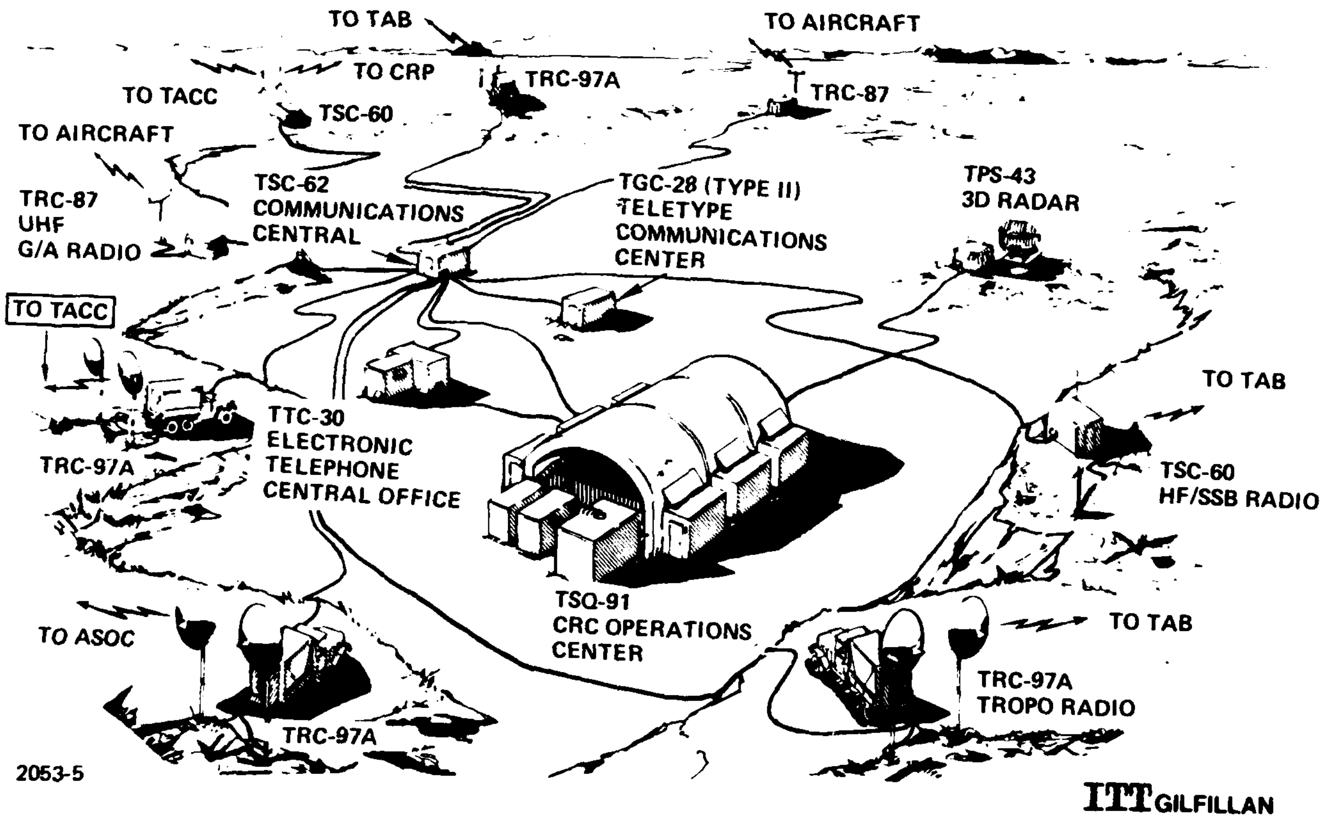
CONTROL AND REPORTING CENTER



KEY ARCHITECTURAL NEEDS

- NEW SURVEILLANCE/CONTROL CONCEPT
- MODULAR DISTRIBUTED C^2
- NETTED SURVEILLANCE
- DISTRIBUTED COMMUNICATIONS
- CONNECTIVITY TO EXISTING AND FUTURE COMMUNICATIONS ASSETS

2053-6

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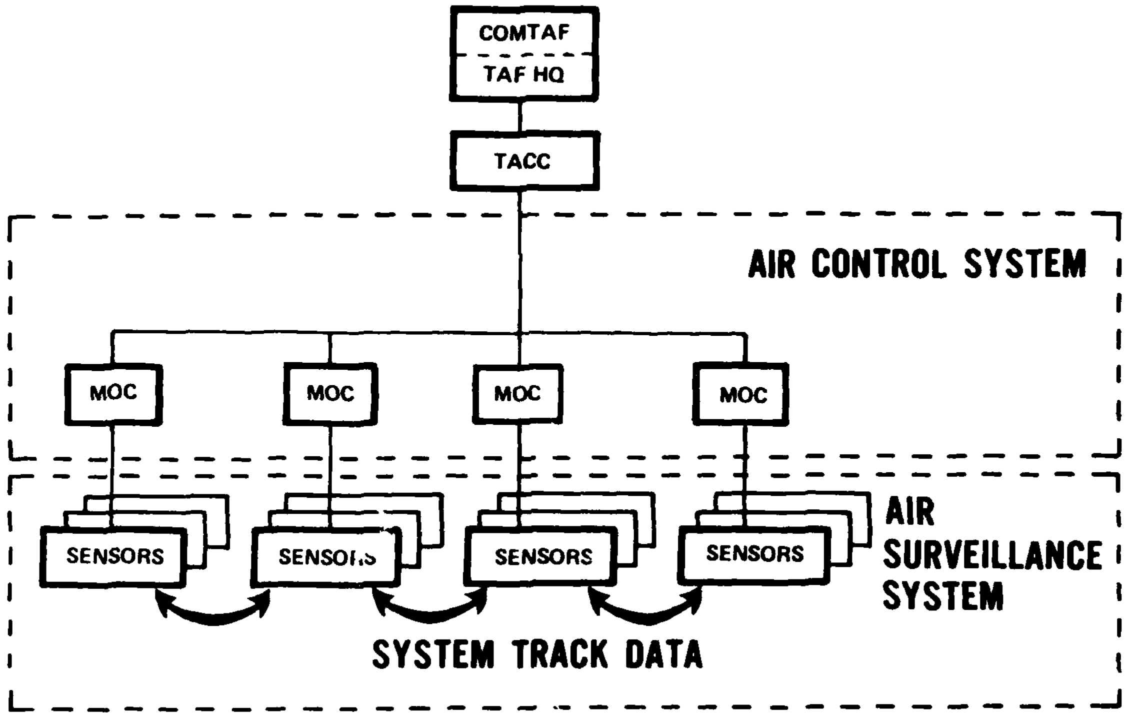
NEW EMPLOYMENT CONCEPT FOR SURVEILLANCE AND AIRSPACE CONTROL FUNCTION



2053-7

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COMPOSITION OF THE MOC

- COMMAND AND CONTROL MODULES
- COMMUNICATIONS NODAL CONTROL ELEMENT
- CIRCUIT SWITCHES
- MESSAGE SWITCH
- REMOTED RADIO PARKS

2053-8

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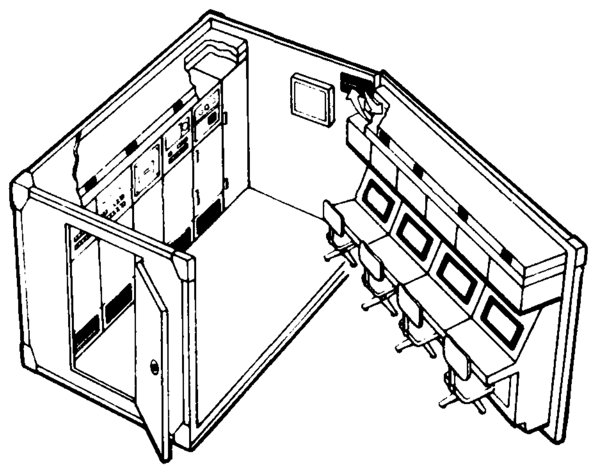
COMMAND AND CONTROL MODULE (CCM)



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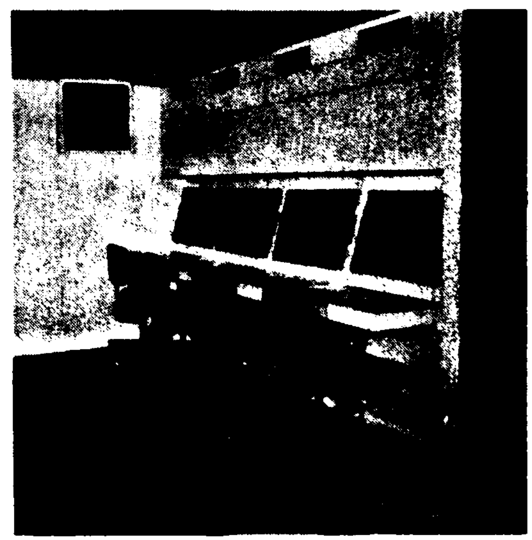

2053-34

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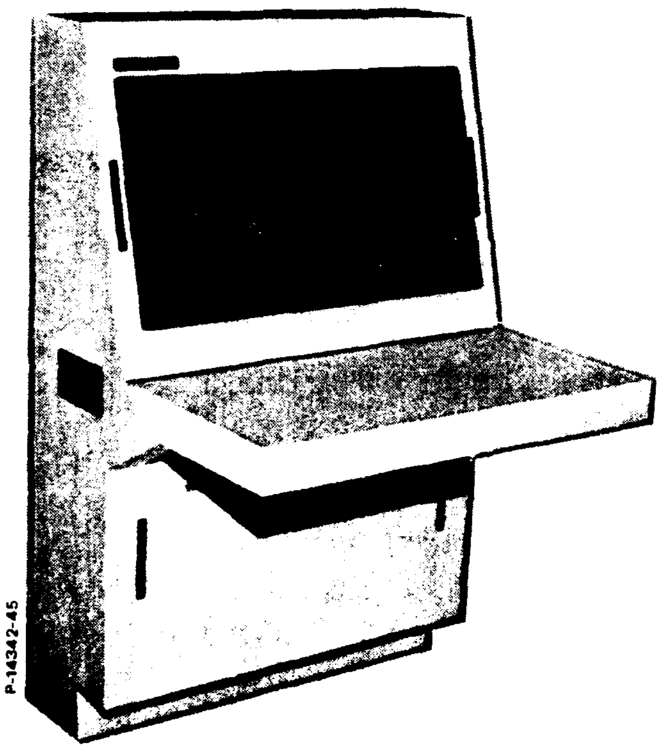
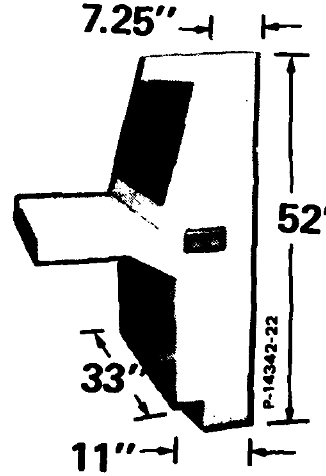
HIGH RESOLUTION FLAT PANEL DISPLAY CONSOLE





2053-33

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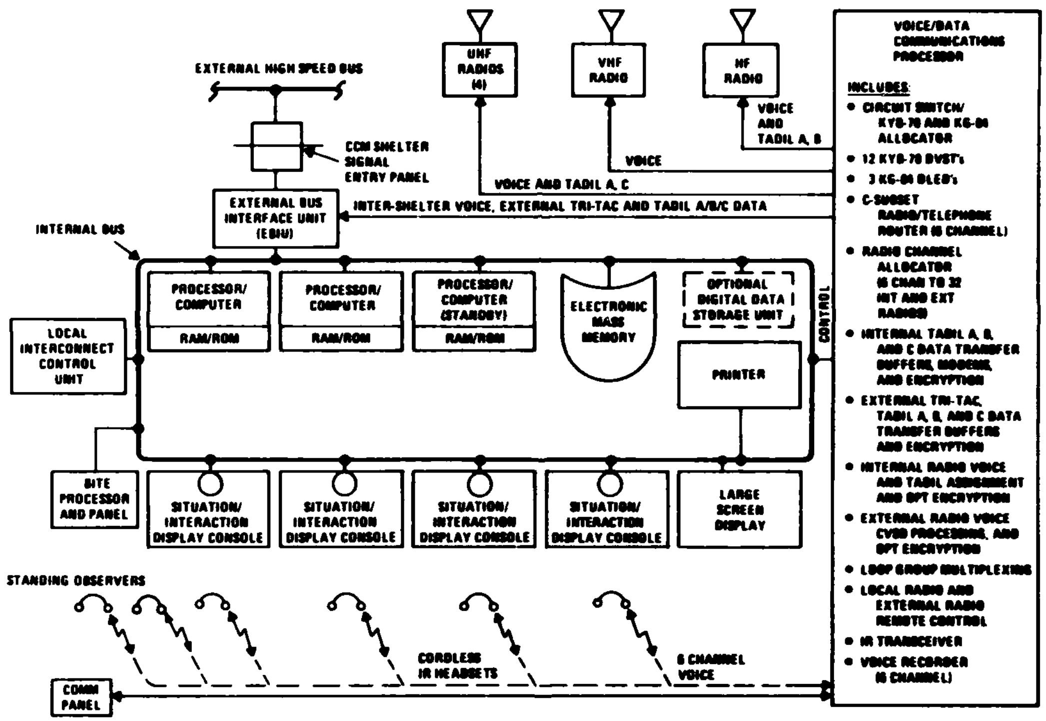
COMMAND AND CONTROL MODULE INTERNAL DIAGRAM



2053-35

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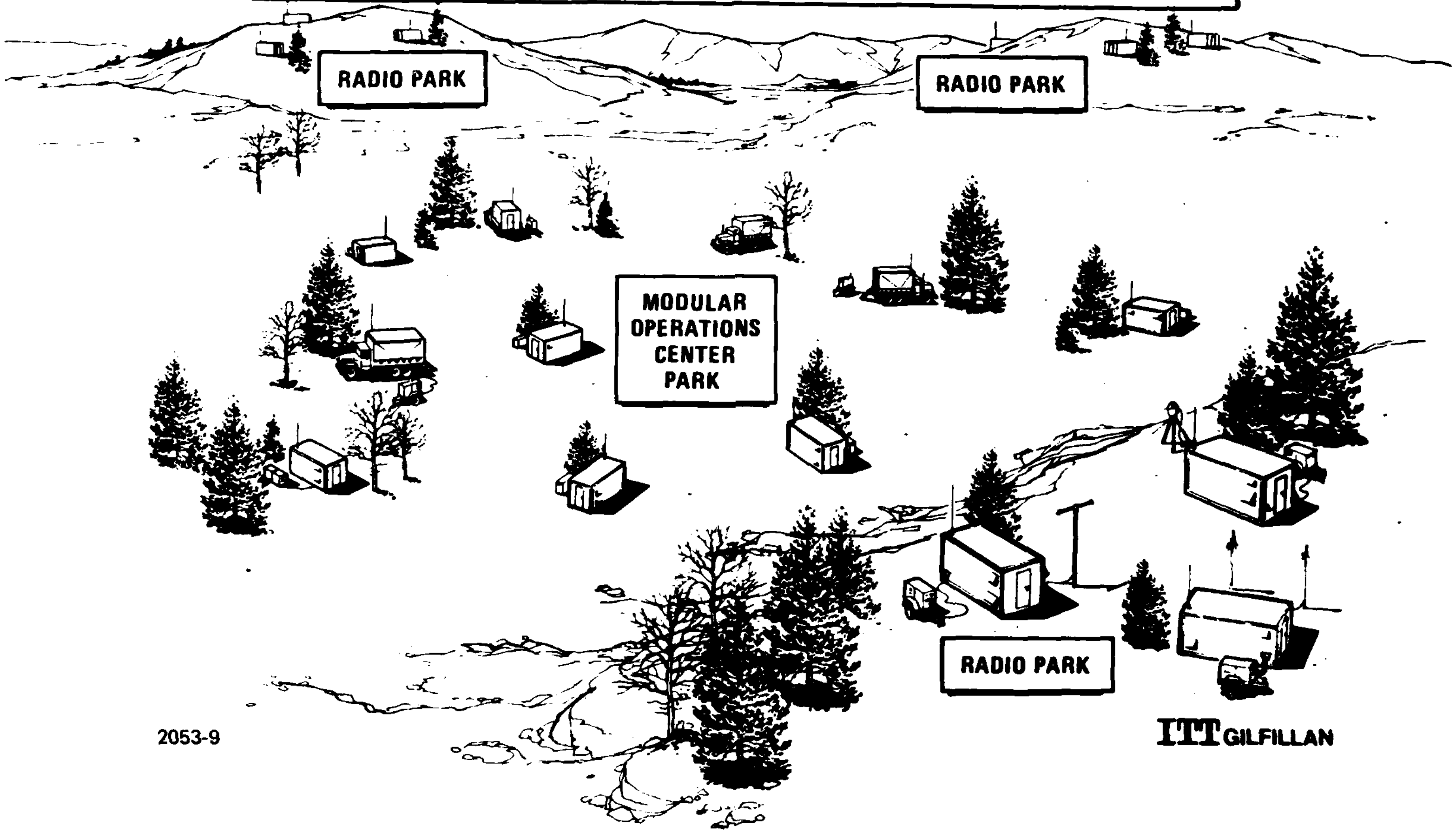
MODULAR OPERATIONS CENTER DEPLOYMENT



2053-9

NETWORK DESIGN GOALS

- SURVIVABILITY
- RELIABILITY
- UNIFORM DISTRIBUTION OF NODE/LINK SURVIVABILITY ACROSS THE NET
- DISTRIBUTED NETWORK MANAGEMENT AND CONTROL
- OPERATIONAL FLEXIBILITY
- UNIVERSAL CONNECTIVITY
- EASE OF USER ACCESS
- NO PROCESSING TO ROUTE OR TO REMOVE MESSAGES
- MAXIMUM TRAFFIC TRANSMISSION RATE – 200 MBITS/SEC

2053-10

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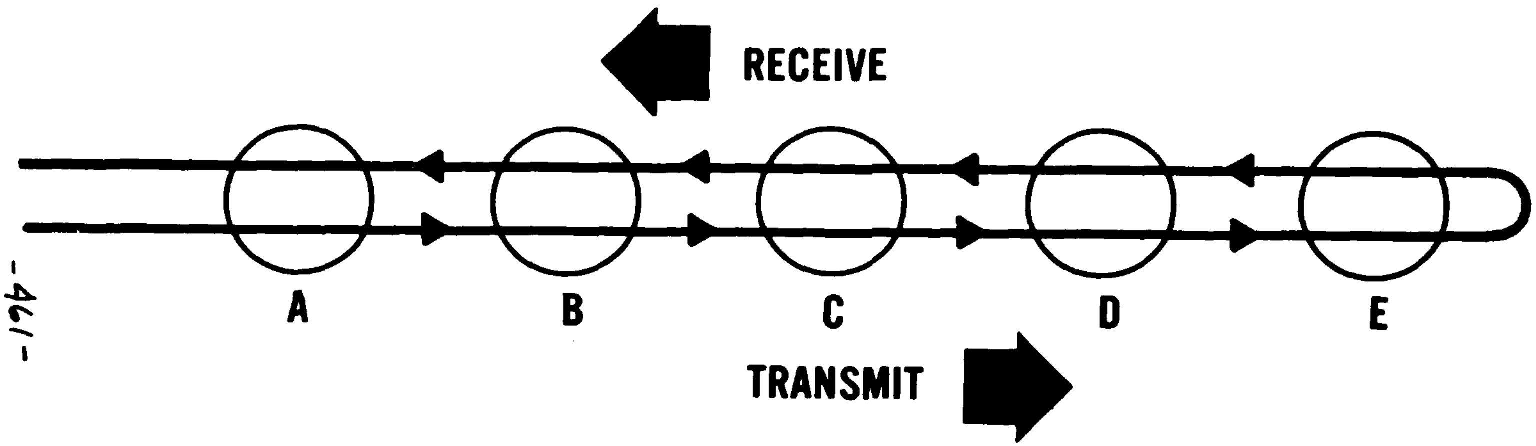
TRANSMIT/RECEIVE OR U-BUS



2053-11

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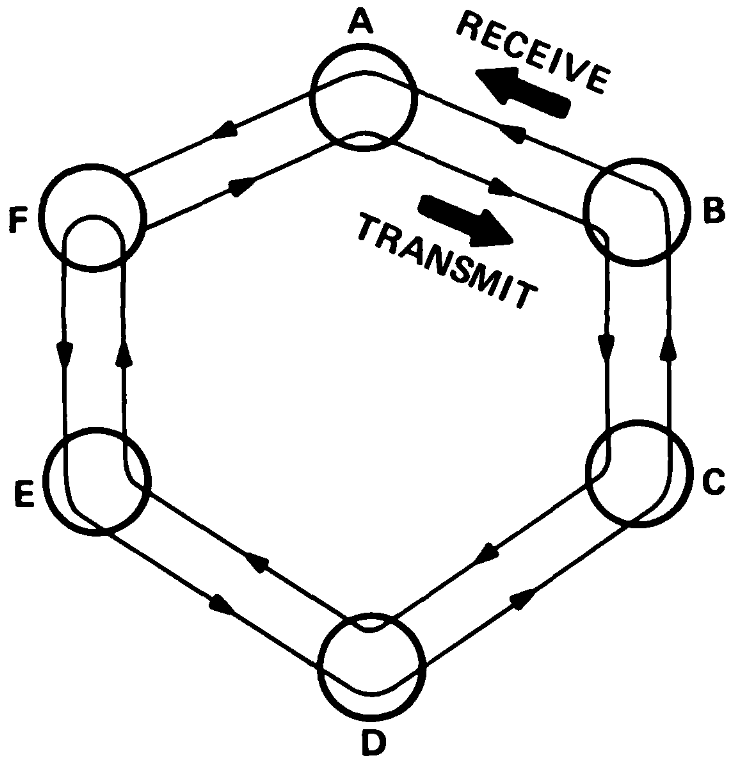
CLOSED U-BUS



2053-12

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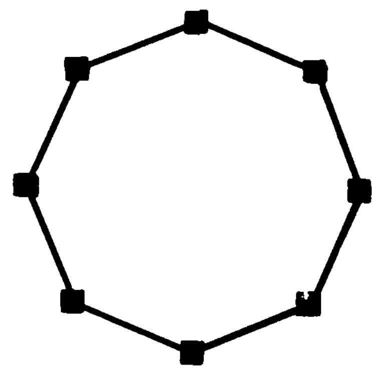
CLOSED U-BUS



2053-13

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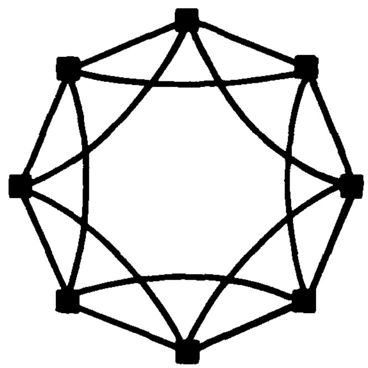
CLOSED U-BUS WITH SINGLE-SKIP BRAID



2053-14

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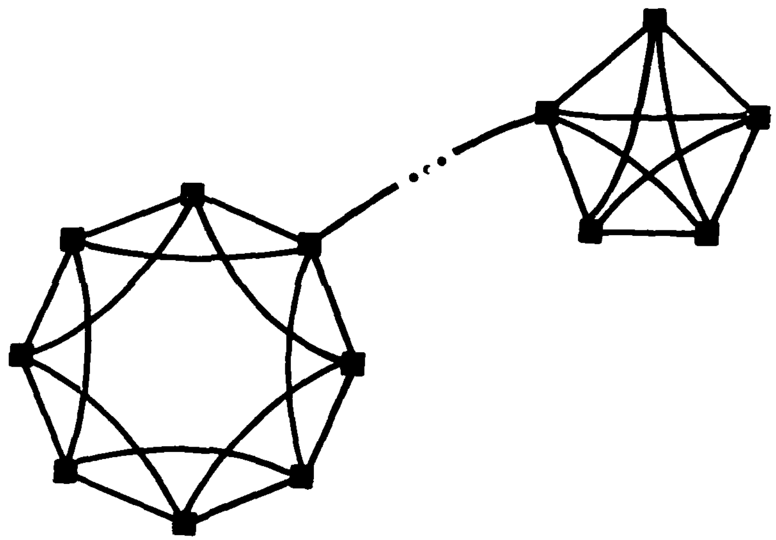
LINKED NETWORKS



2053-15

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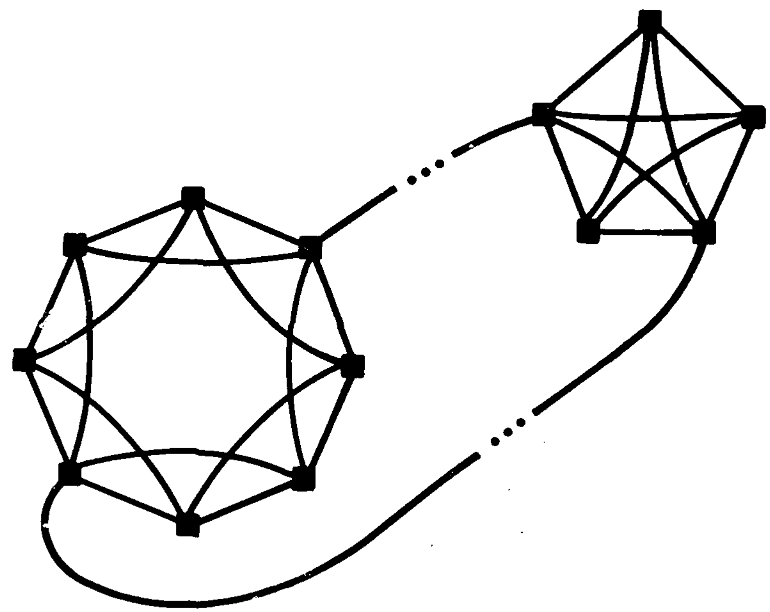
LINKED NETWORKS WITH REDUNDANT STRUCTURING



2053-16

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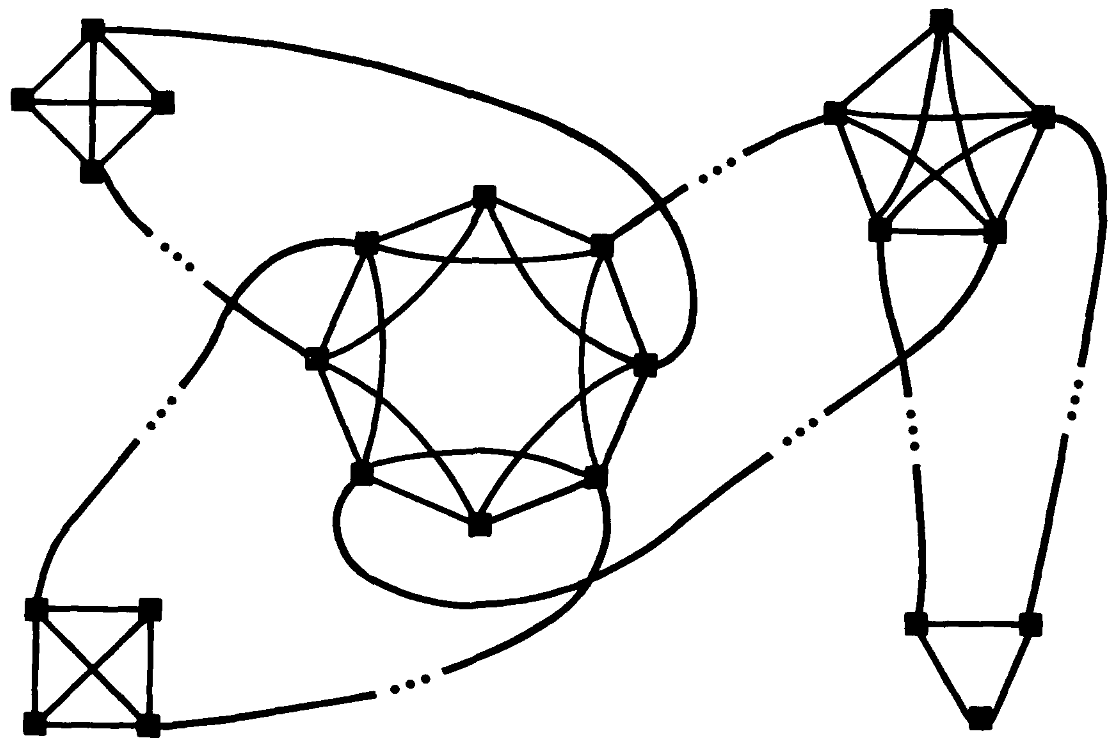
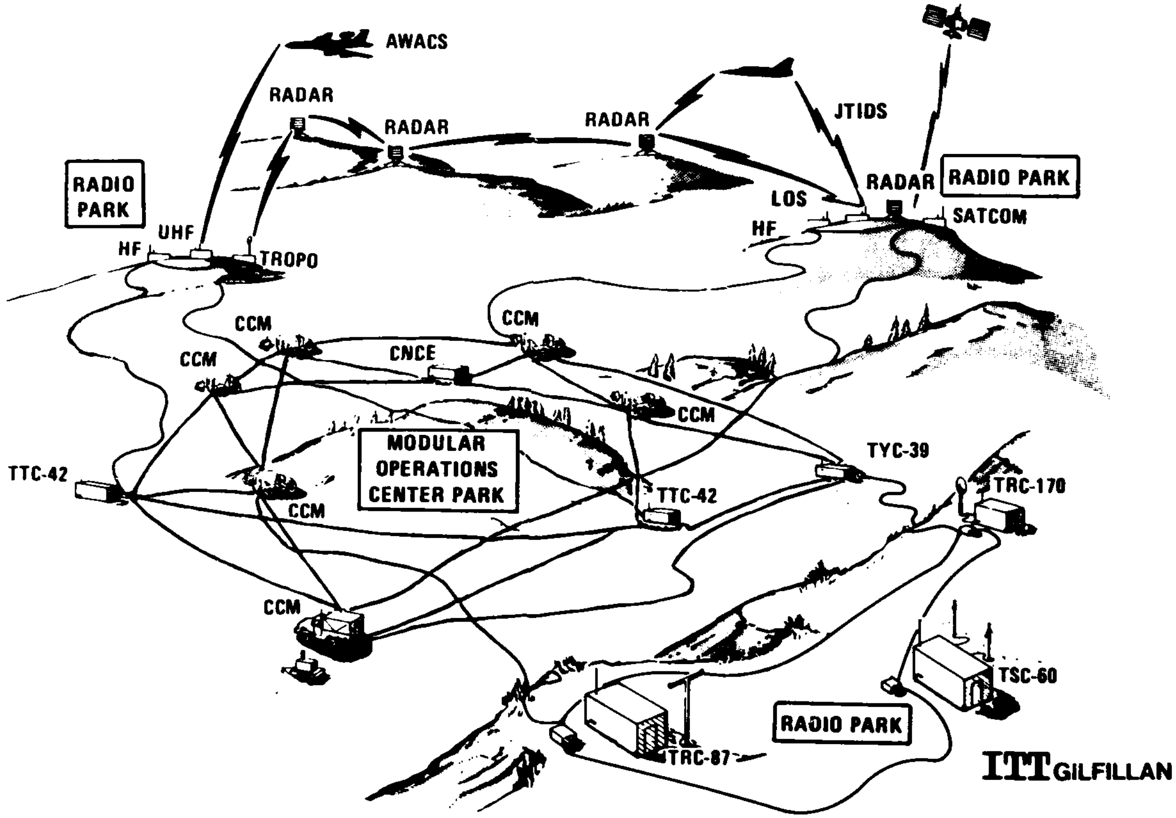
FULLY IMPLEMENTED SYSTEM OF NETWORKS



2053-17

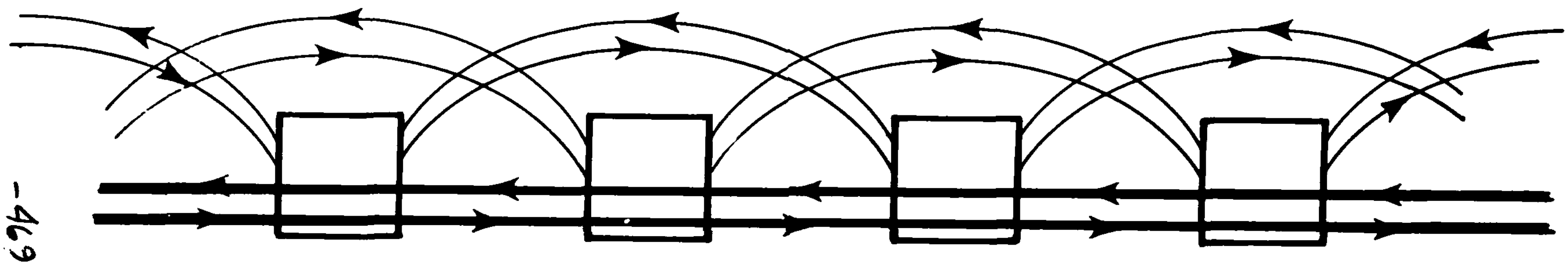
ITT GILFILLAN

MODULAR OPERATIONS CENTER



2053-18

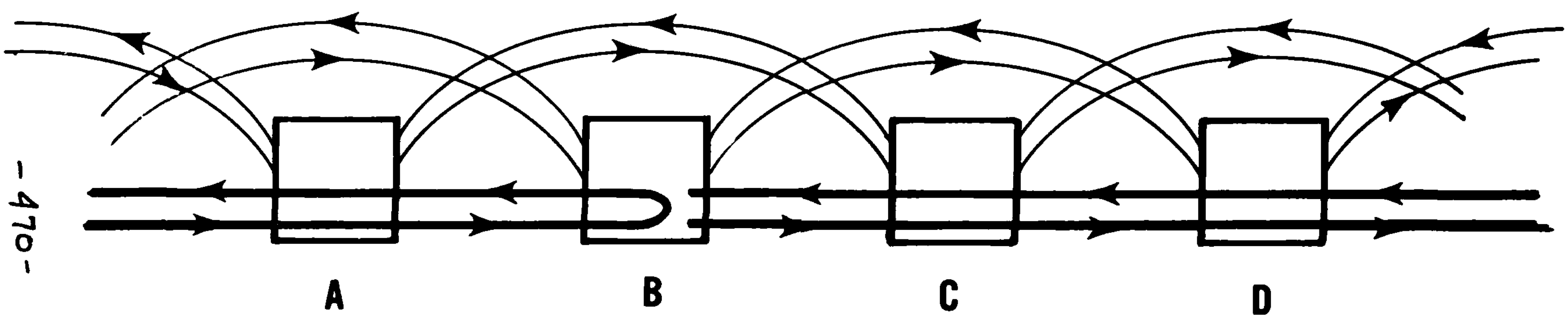
SWITCHING CONFIGURATION
PRIMARY PATH



2053-19

ITT GILFILLAN

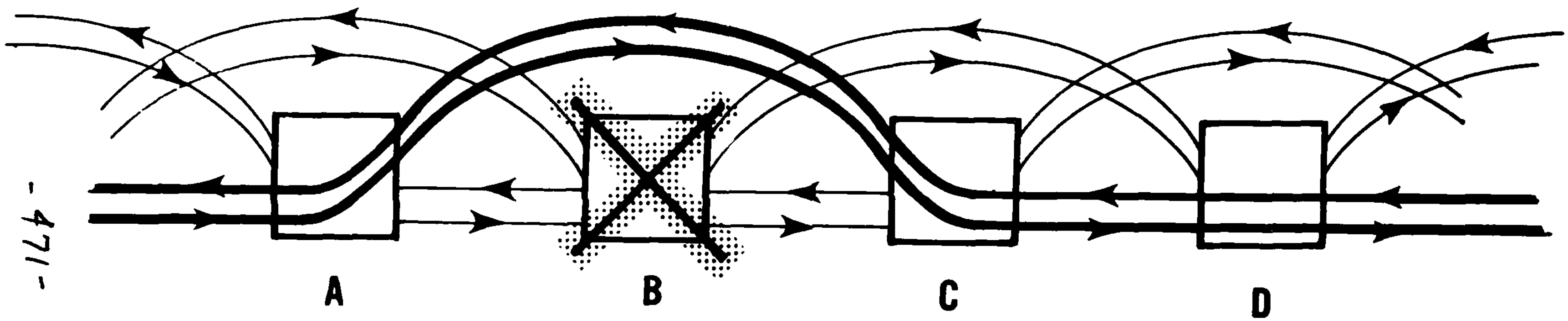
SWITCHING CONFIGURATION START/END NODE



2053-20

ITT GILFILLAN

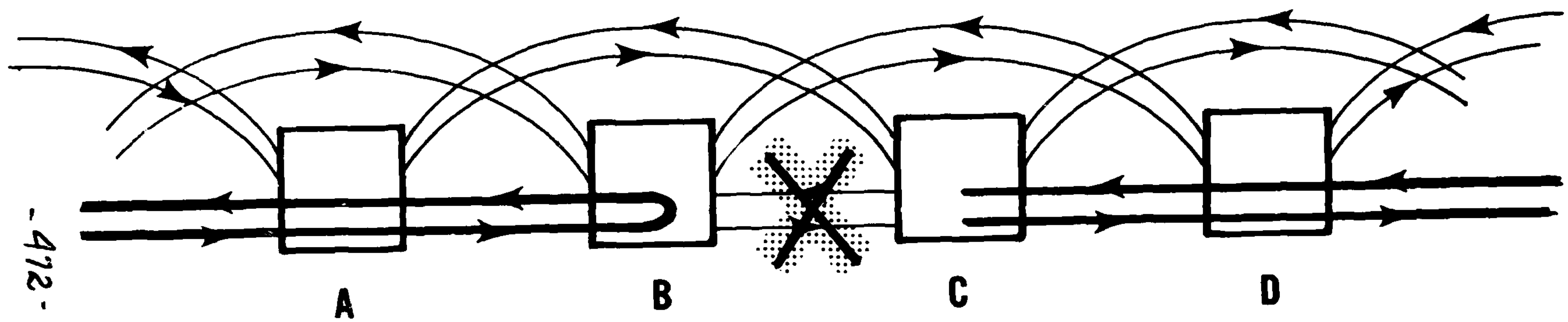
SWITCHING CONFIGURATION
LOSS OF NODE



2053-21

ITT GILFILLAN

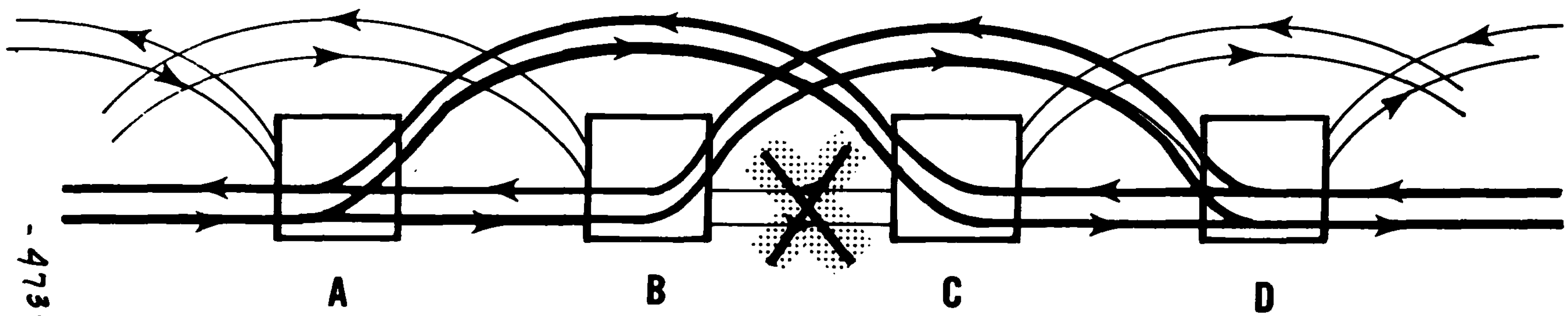
SWITCHING CONFIGURATION LOSS OF PRIMARY LINK



2053-22

ITT GILFILLAN

SWITCHING CONFIGURATION
LOSS OF PRIMARY LINK

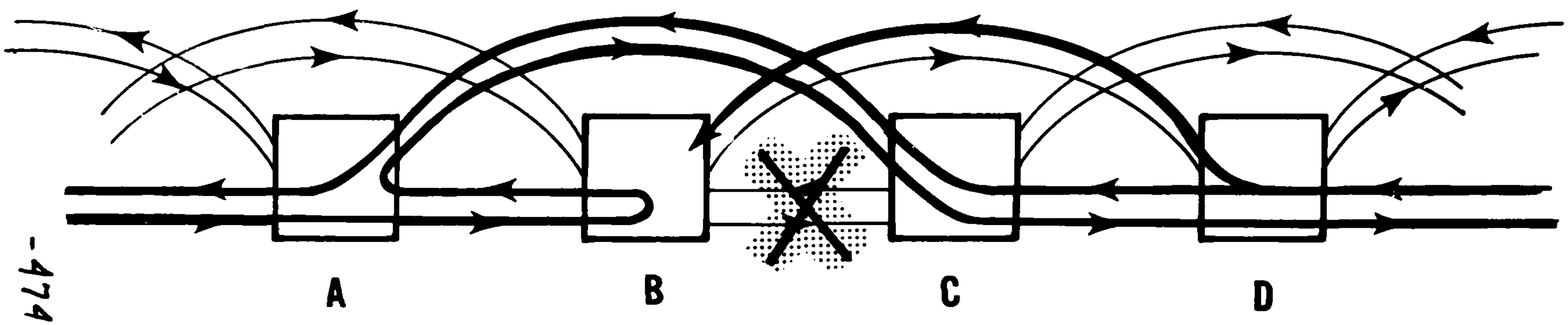


INAPPROPRIATE SOLUTION!

2053-23

ITT GILFILLAN

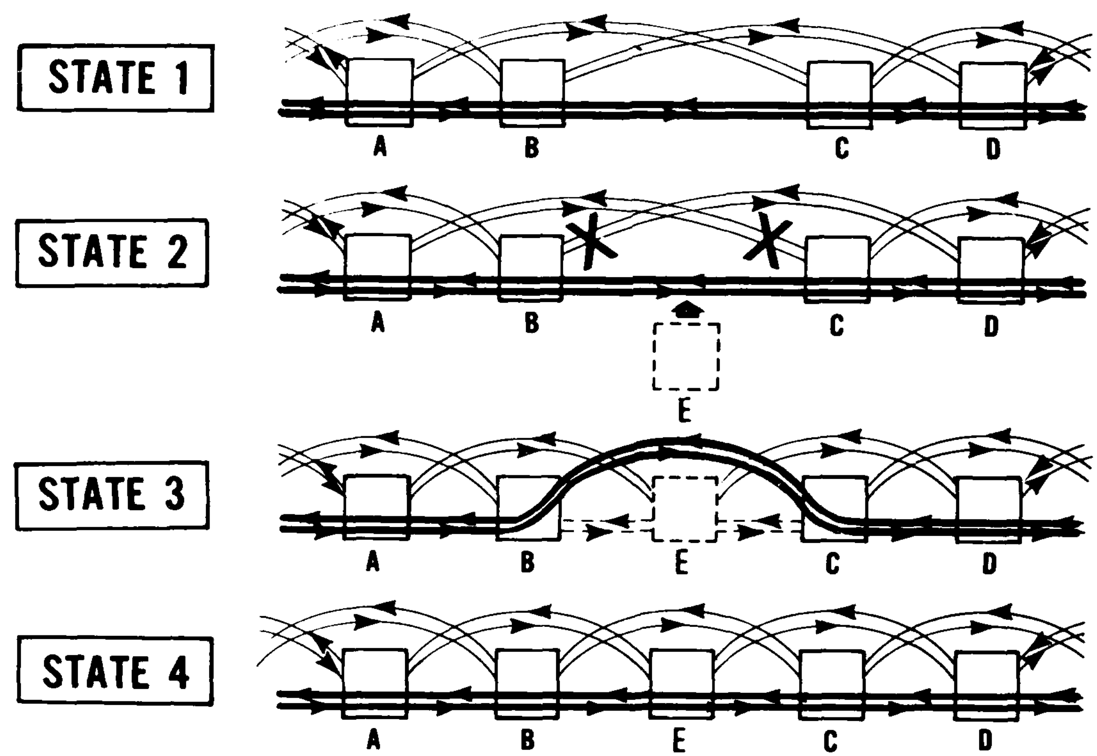
SWITCHING CONFIGURATION
LOSS OF PRIMARY LINK



2053-24

ITT GILFILLAN

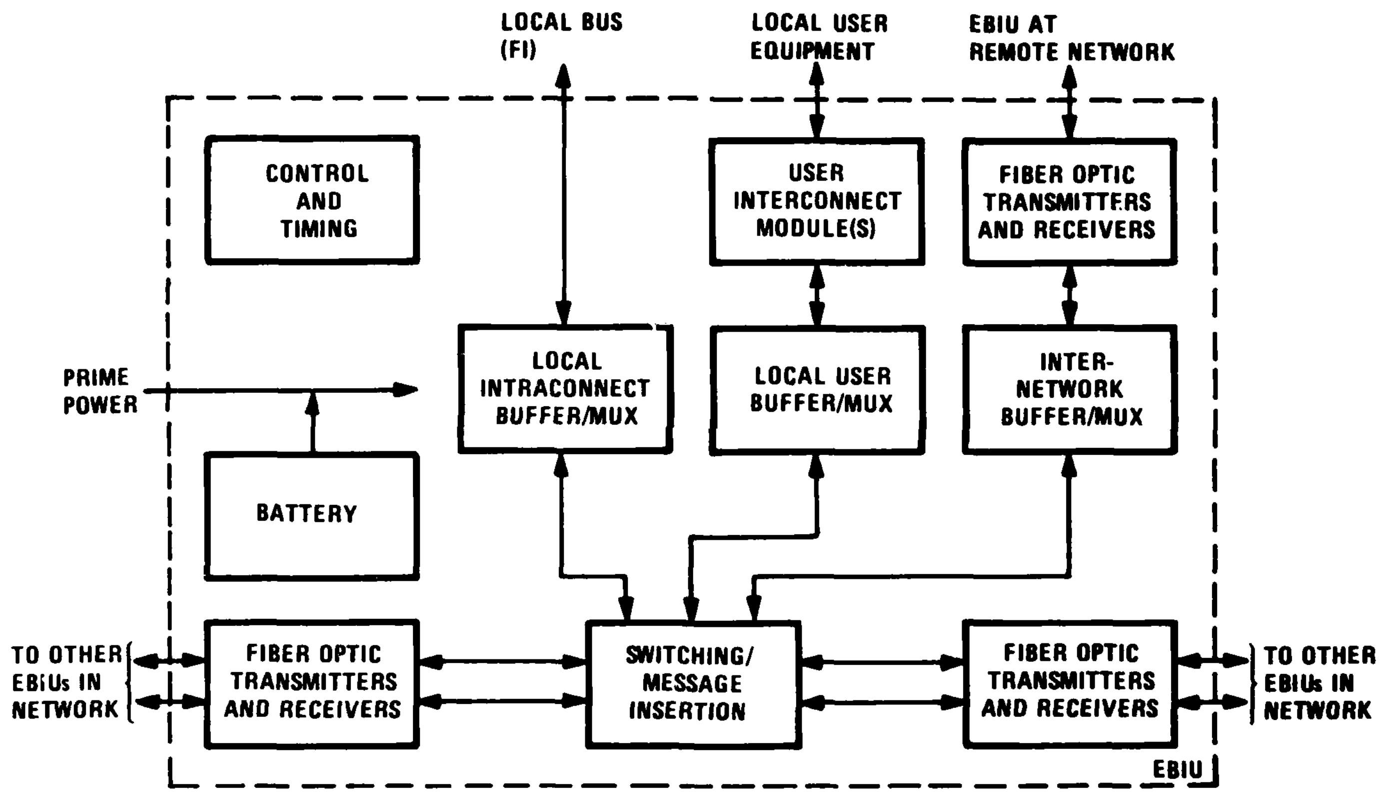
ADDITION OF NODE TO EXISTING NETWORK



2053-40

ITT GILFILLAN

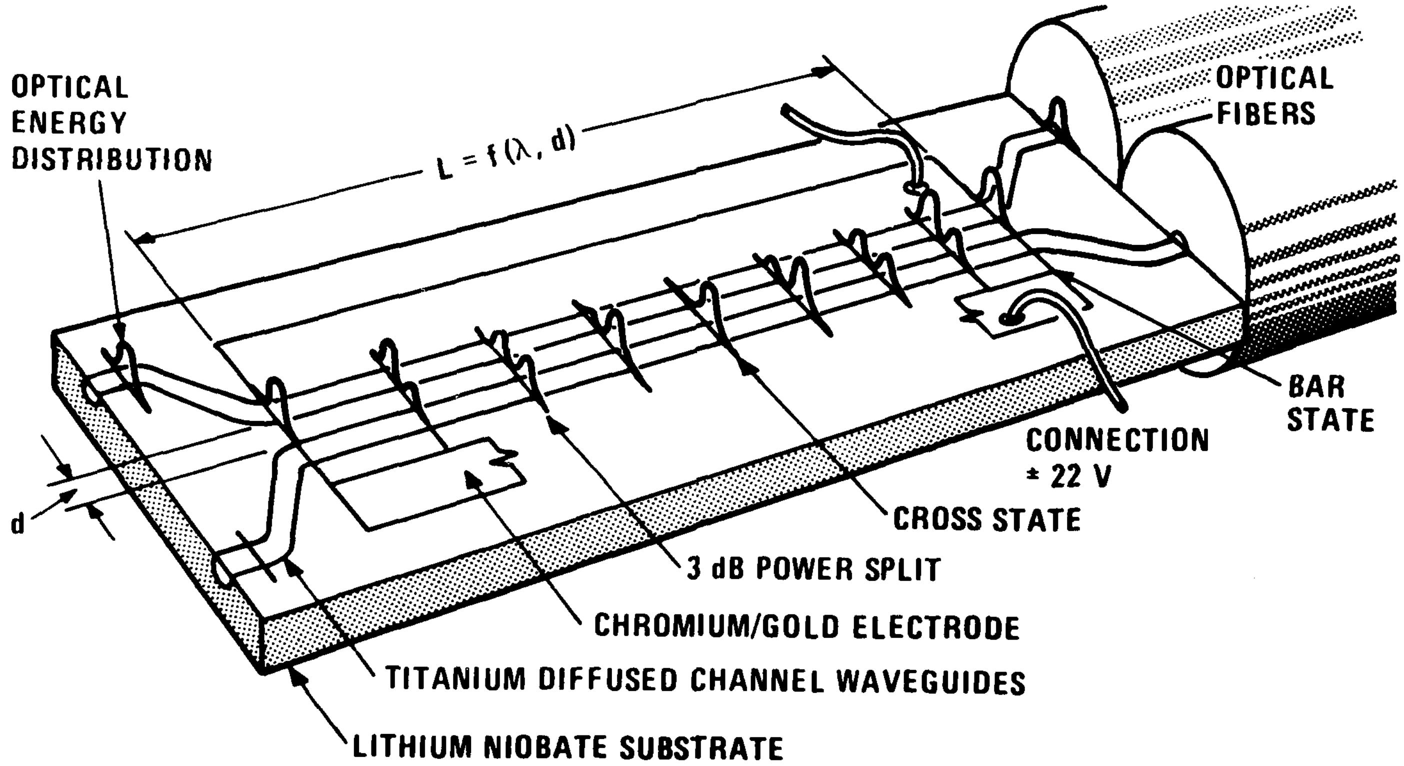
EXTERNAL BUS INTERFACE UNIT (EBIU)



2053-25

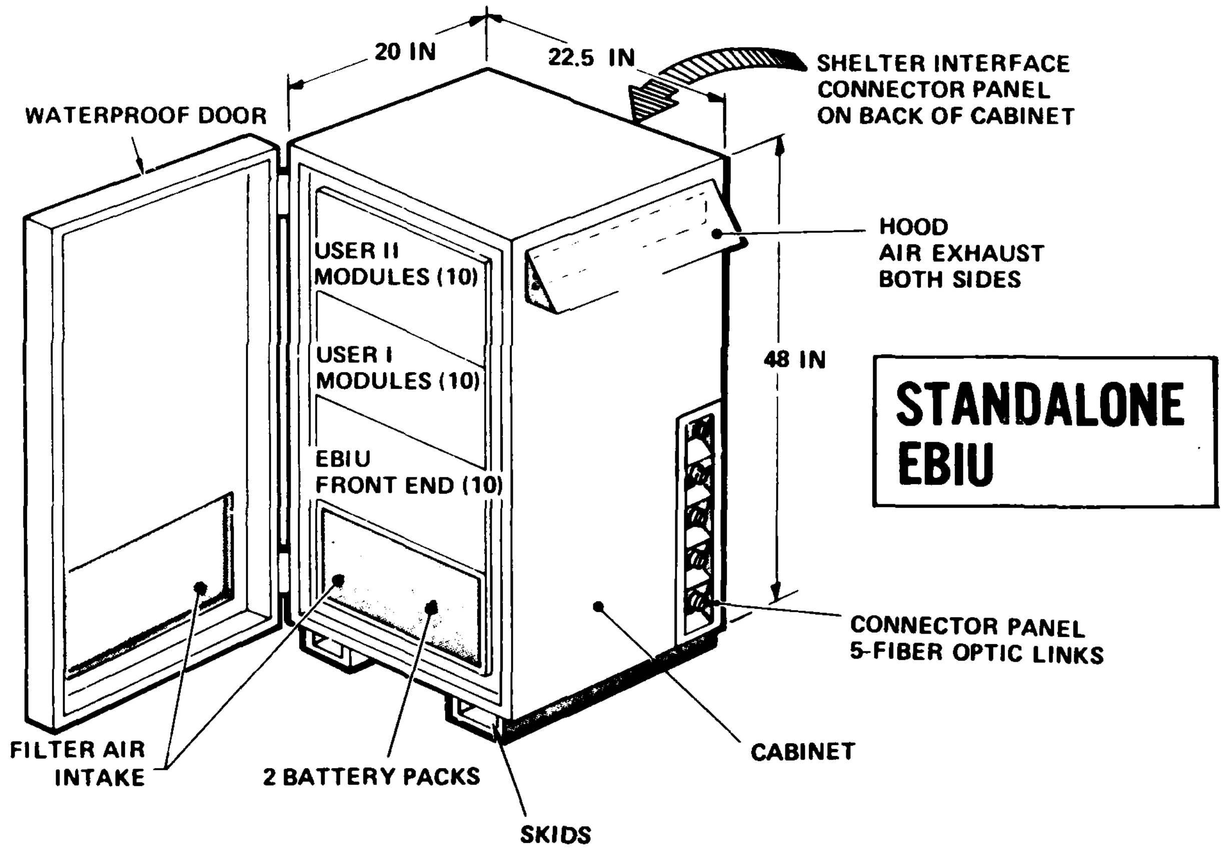
ITT GILFILLAN

OPTICAL DIRECTIONAL COUPLER/SWITCH



2053-26

ITT GILFILLAN



2053-27

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IMPACT OF THE LAN ON COMMUNICATIONS

2053 28

ITT GILFILLAN

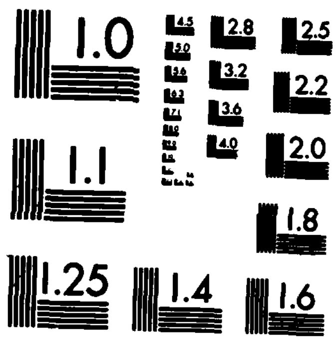
AD-A126 110 PROCEEDINGS OF CONFERENCE ON LOCAL AREA MILITARY NETWORKS GRIFFISS AFB NEW YORK 28-30 SEPTEMBER 1982(U) ROME AIR DEVELOPMENT CENTER GRIFFISS AFB NY 6/6

UNCLASSIFIED D B WARMUTH ET AL. 1982 F/G 17/2 NL

END

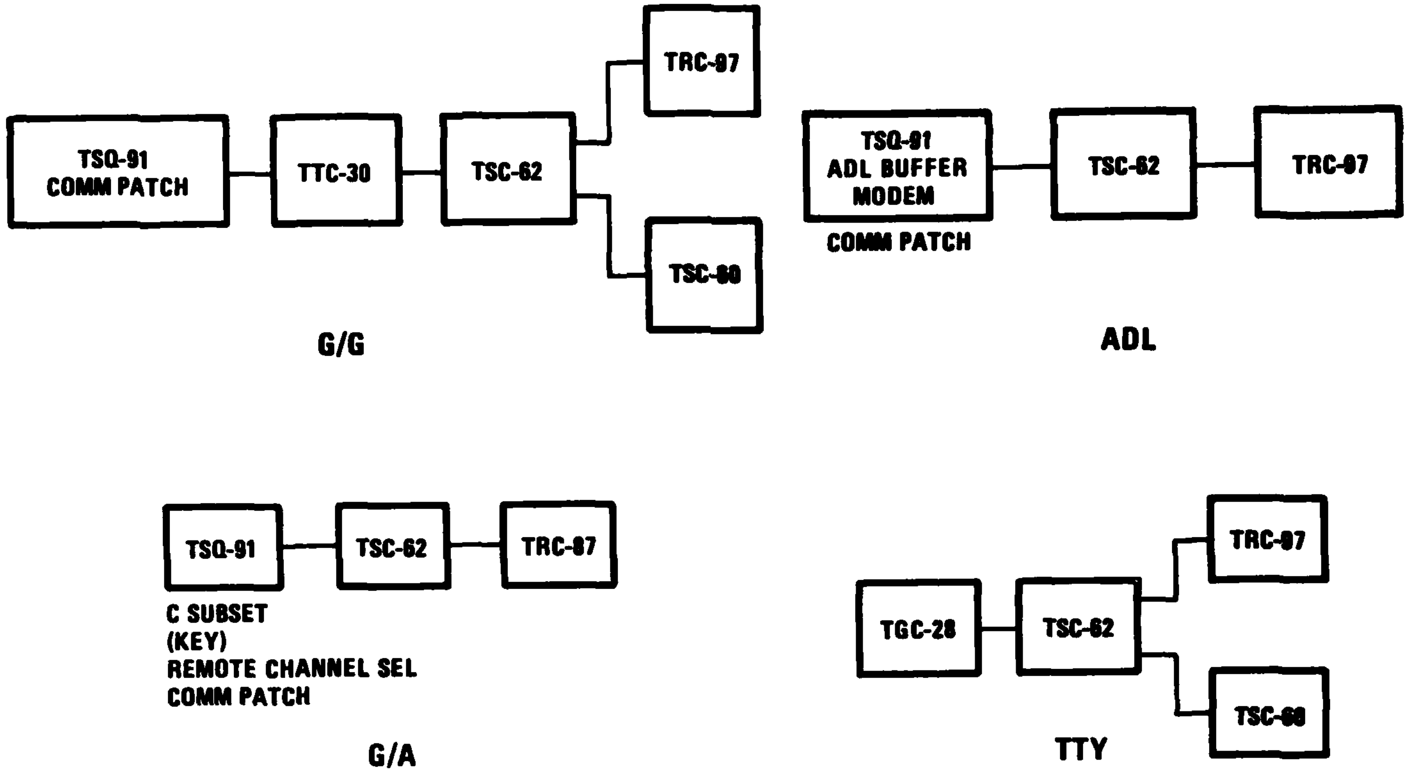
FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

OBSOLETE ANALOG
CRC/CRP COMMUNICATION STRUCTURES



2053-29

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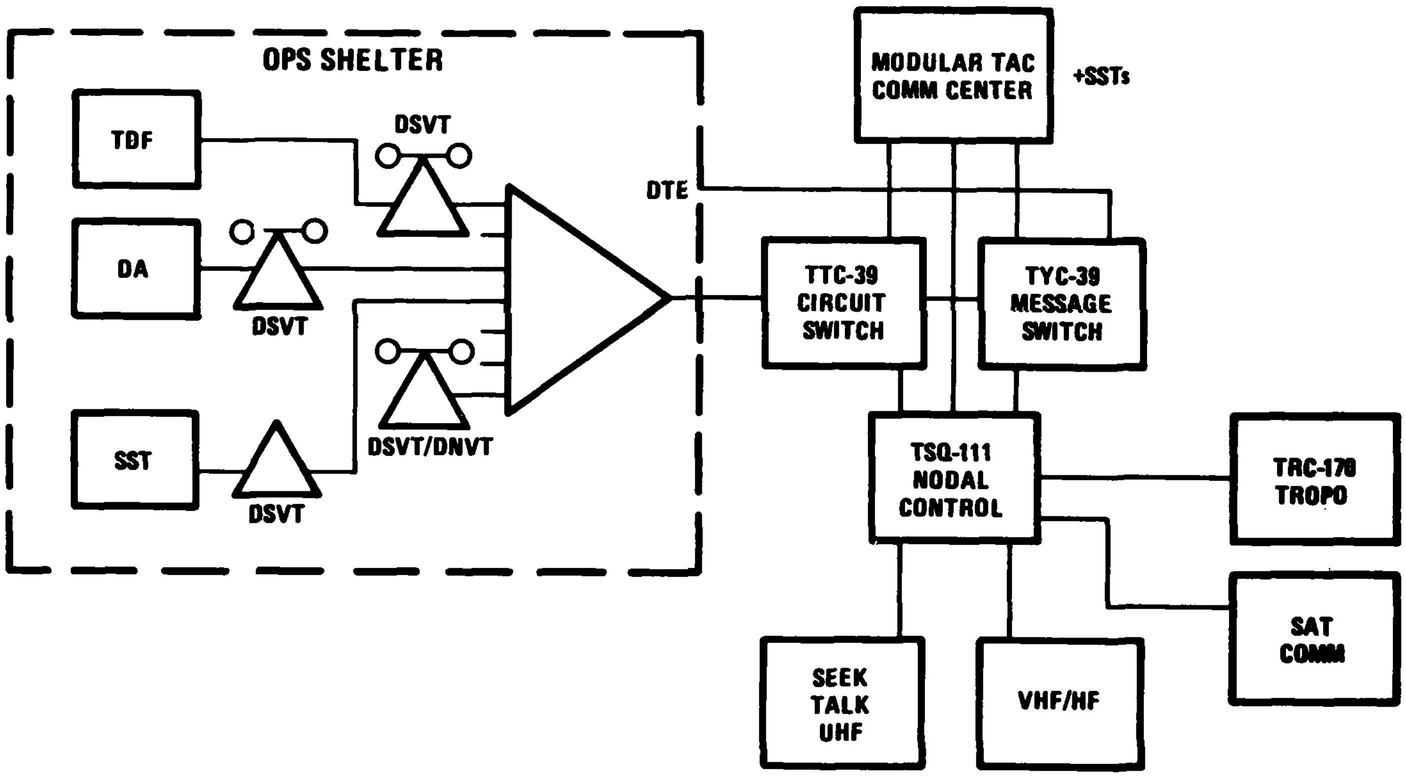
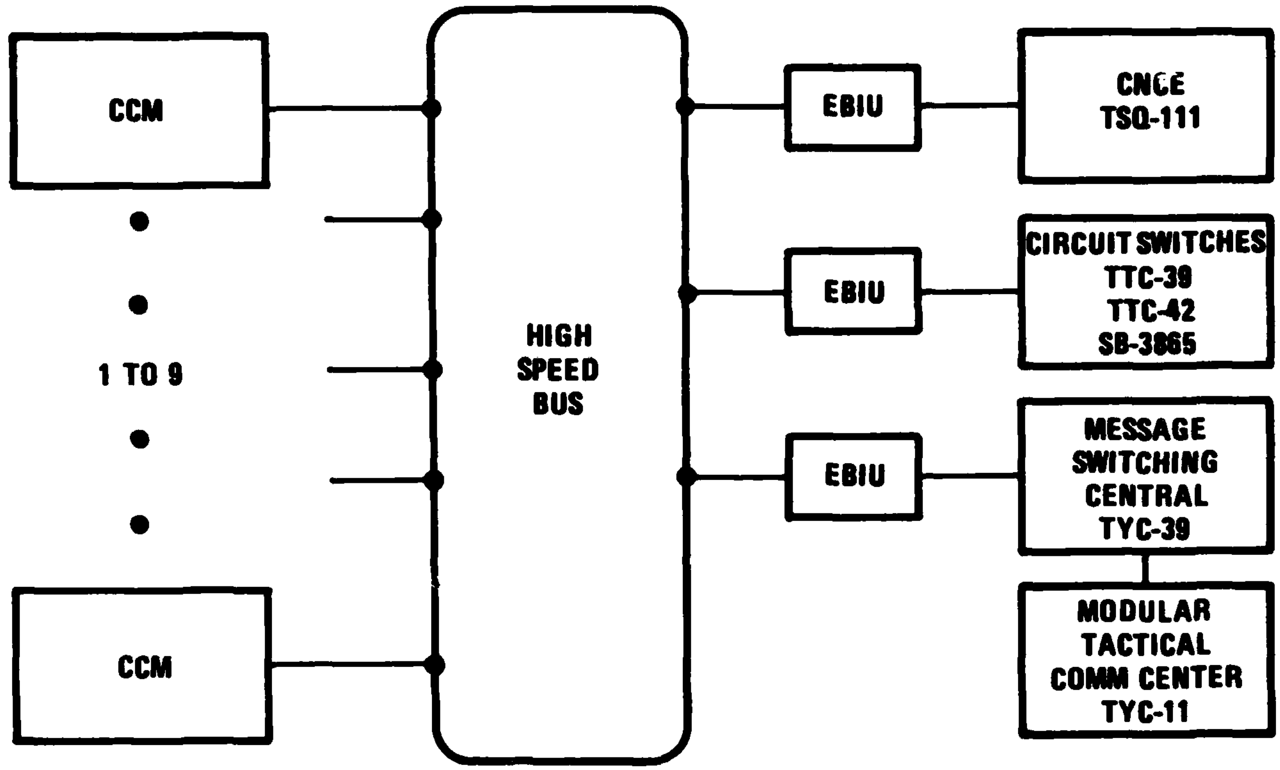
TRI-TAC COMMUNICATION STRUCTURES



2053-30

ITT GILFILLAN

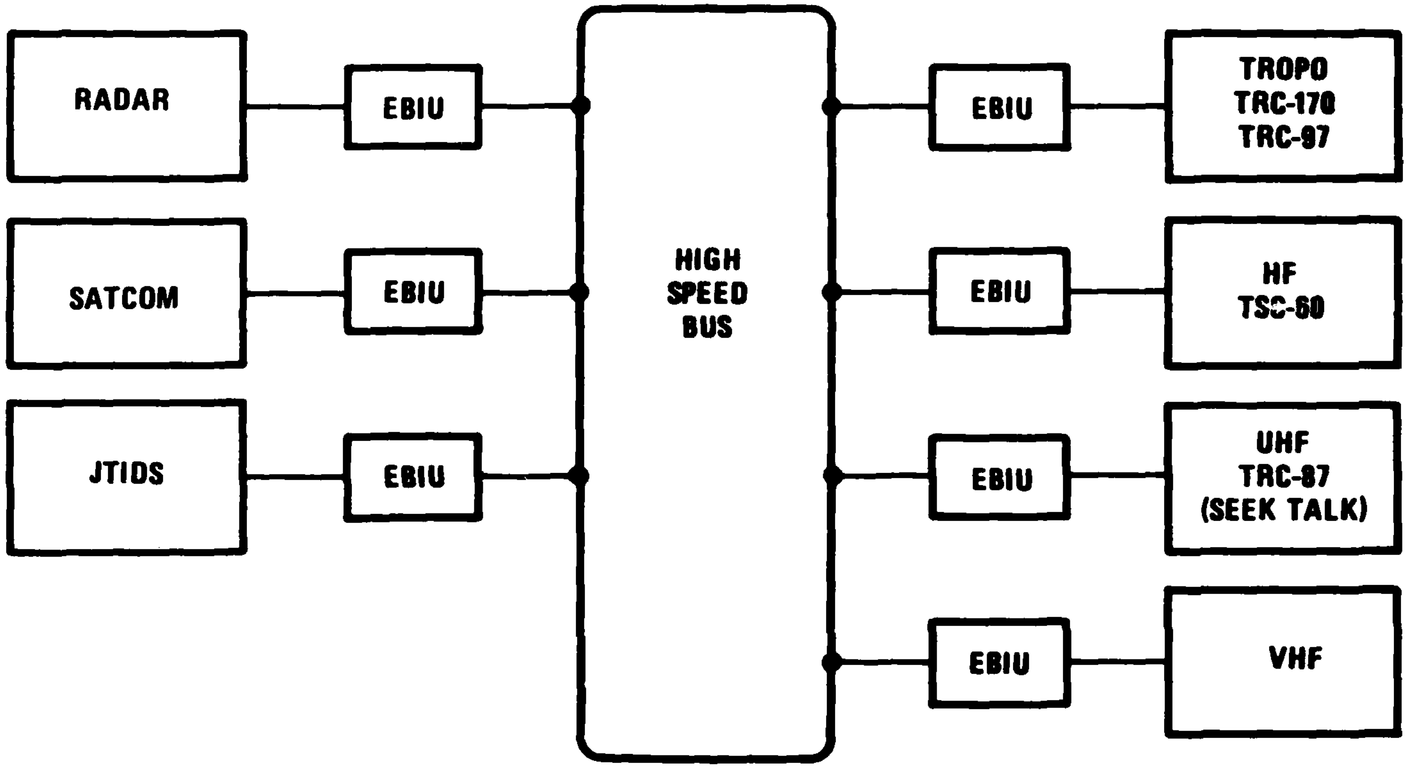
MODULAR OPERATIONS CENTER



2053-31

ITT GILFILLAN

RADIO PARK



2053-32

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OPERATIONAL IMPLICATIONS OF THE DISTRIBUTED ARCHITECTURE

2053-36

ITT GILFILLAN

MAJOR CHALLENGES

- FUNCTIONAL INTEGRITY
- DEGRADED MODE CAPABILITY

2053-37

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SOLUTION

- REDEFINITION OF OPERATIONAL CONCEPTS AND FUNCTIONS
- CREATION OF NEW ORGANIZATION
- OPERATOR TRAINING
- INFUSION OF NEW TECHNOLOGY
- EQUIPMENT UTILIZATION

2053-38

ITT GILFILLAN

CONCLUSION

TACTICAL UNITS CONSISTING OF MODULAR, DISTRIBUTED ELEMENTS THAT ARE INTERCONNECTED BY LOCAL AREA NETWORKS ARE <u>MORE SURVIVABLE</u> AND HAVE <u>GREATER OPERATIONAL FLEXIBILITY</u> THAN TACTICAL UNITS THAT ARE FUNCTIONALLY AND PHYSICALLY CENTRALIZED.

2053-39

ITT GILFILLAN

Standardization (0800-1000 30 Sep)

Session Chairman: Mr. James L. Davis - RADC/DCLW

"Protocol Standardization," Dr. Rona Stillman, Hq USAF/ACD

Protocol standards for local area networks with military applications.

"Implementation and Application of DoD Standard Protocols in Local Area Networks," Mr. John K. Summers, MITRE Corp.

Selection and implementation of DoD standard protocols in microprocessors; evolution strategies and performance results.

"National Bureau of Standards Activities in LAN's," Mr. Dan Stocksberry, National Bureau of Standards

Discussion of LAN selection criteria and performance measurements of LANs.

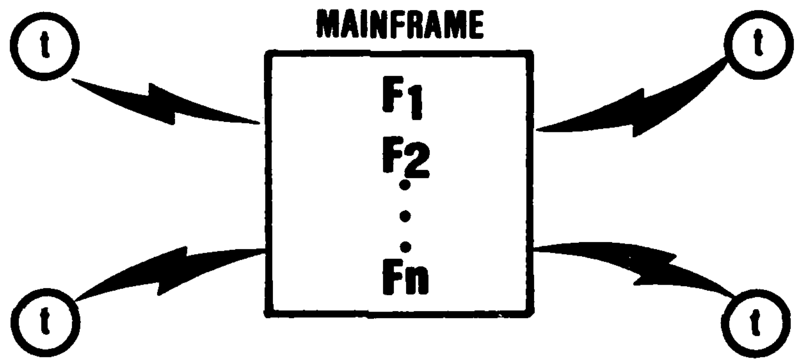
"NATO Standardization for Local Area Networks," Mr. Steve Anderson, and Mr. Dennis Abbot, Sperry Univac

Local Area Network Standardization activities in NATO will be discussed with emphasis on ship system integration.

PIVOTAL TECHNOLOGIES

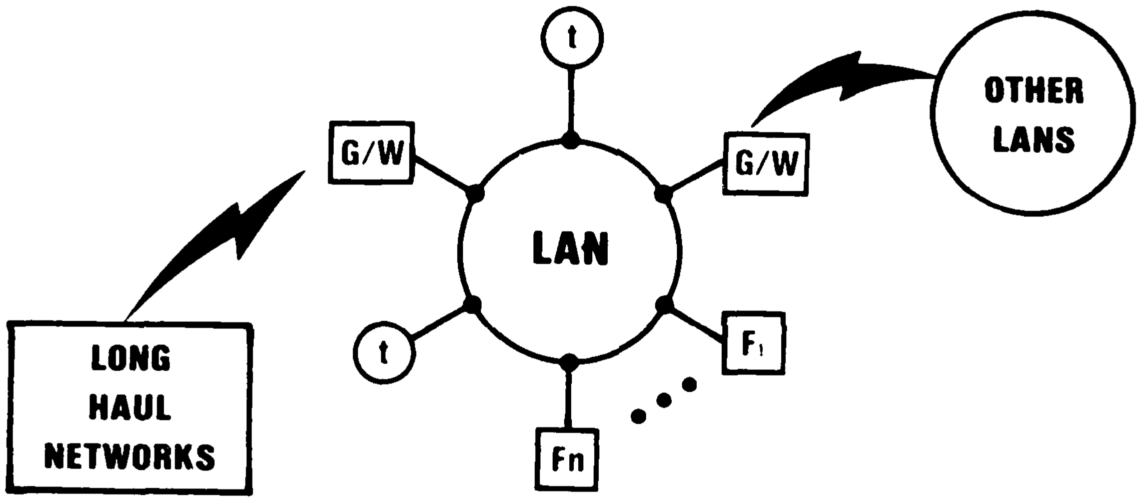
- INEXPENSIVE, POWERFUL MICROCOMPUTERS
- INEXPENSIVE, HIGH BANDWIDTH COMMUNICATIONS
- PROVEN EFFICIENCY OF PACKET SWITCHING FOR BURSTY COMPUTER COMMUNICATIONS

OLD ARCHITECTURE MODEL: CENTRALIZED MAINFRAME, DEDICATED COMMUNICATIONS



- EXPENSIVE MAINFRAME, COMMUNICATIONS
- ALL HARDWARE FROM SINGLE VENDOR
- NOT EASILY EXPANDED
- MULTILEVEL SECURITY VIA KERNEL TECHNOLOGY TOO DIFFICULT
- "EVOLUTION" BY WHOLESALE REPLACEMENT

NEW ARCHITECTURE MODEL: LOCAL AREA NETWORK, CATENET



- FUNCTIONALLY DEDICATED PROCESSORS
- ECONOMICAL COMMON USER LONG HAUL COMMUNICATION
- EASILY EXPANDED TO ACCOMODATE NEW USERS, SERVICES
- POTENTIAL EXISTS FOR
  - VENDOR INDEPENDENCE
  - GRACEFUL INCREMENTAL EVOLUTION
  - MULTILEVEL SECURITY VIA ENCRYPTION TECHNOLOGY
  - TRUE RESOURCE SHARING

KEY TO REALIZING LAN POTENITAL: LEARN FROM PAST HISTORY

- MAJOR HARDWARE IMPROVEMENTS/NEW GENERATIONS COME QUICKLY, CHEAPLY
- SOFTWARE IS THE PROBLEM
  - LATE
  - LONG TO MATURITY, STABILITY
  - EXPENSIVE TO BUILD, MAINTAIN, TRANSPORT
- MULTILEVEL SECURITY VIA SOFTWARE SEPARATION ALONE IS TOO HARD, TOO EXPENSIVE, TOO SLOW
- GATEWAY TECHNOLOGY NEWER, LESS WELL DEVELOPED THAN INTRANETWORK SWITCHING

STRATEGIC APPROACH

- BUILD SOFTWARE TO SPAN GENERATIONS OF HARDWARE
  - MODULAR SOFTWARE
  - HIGH LEVEL STANDARD LANGUAGES
  - HARDWARE INSENSITIVE
- PLAN TO REPLACE HARDWARE BY NEWER HIGHER PERFORMANCE/PRICE OFFERINGS
  - MODULAR HARDWARE
  - VENDOR INDEPENDENCE AT LOGICAL INTERFACES
- BE WILLING TO PAY
  - SYSTEM PERFORMANCE
  - SOFTWARE NOT OPTIMIZED FOR SPEED, MEMORY UTILIZATION
  - INITIAL COST - BUY MORE HARDWARE
- MOUNT ALTERNATIVE ATTACK ON MULTILEVEL SECURITY BASED UPON ENCRYPTION, INTIMATELY RELATED TO PROTOCOLS
- SIMPLIFY GATEWAYS BY JUDICIOUS PROTOCOL MANAGEMENT

UNDERLYING REQUIREMENT: STANDARD, LAYERED PROTOCOLS

BASIC LEVEL	SUBLEVELS
APPLICATIONS FUNCTIONS	USER ORIENTED APPLICATIONS
END-TO-END TRANSPORT	HOST-TO-HOST
	INTERNETWORK
TRANSMISSION	NETWORK PACKET EXCHANGE
	FRAME TRANSFER
	PHYSICAL INTERFACE

SOME LAN CHOICES ARE SECOND ORDER: CHARACTERISTICS OF LAN

- TOPOLOGY
  - RING
  - BUS
  - MESH
- MEDIUM
  - TWISTED PAIR
  - COAXIAL CABLE
  - FIBRE OPTICS
- ACCESS MECHANISM
  - CONTENTION (CSMA, CSMA/CD)
  - DETERMINISTIC
- MODULATION
  - BASEBAND
  - BROADBAND

SOME CHOICES ARE FIRST ORDER: PROTOCOLS AND THEIR MANAGEMENT

- LAYERED ARCHITECTURE OF VENDOR INDEPENDENT PROTOCOLS
- CHOICE OF PROTOCOLS, ESPECIALLY AT INTERNETWORK LAYER AND ABOVE
- STANDARDIZATION AND EVOLUTION OF THESE PROTOCOLS

PROTOCOLS ARE COMPLEX OBJECTS

- SERVE ASYNCHRONOUS PROCESSES
- EXHIBIT TIME DEPENDENT, LOAD DEPENDENT BEHAVIOR
- EXPENSIVE TO DESIGN, SPECIFY, DEVELOP, TEST
- MATURE SLOWLY
- GENERALLY IMPLEMENTED IN SOFTWARE

DOD STANDARD PROTOCOLS: TCP/IP

- MOST WIDELY IMPLEMENTED, TESTED STANDARD TRANSPORT PROTOCOLS AVAILABLE TODAY
- MEET DOD REQUIREMENTS, SUPPORT HIGHER LEVEL USER ORIENTED SERVICE PROTOCOLS
- IMPLEMENTED SUCCESSFULLY ON LAN
- OPERATE WITH PLI's, WHICH PROVIDE END-TO-END SECURITY
- ARE THE CONTEXT FOR ONGOING RESEARCH IN MULTILEVEL SECURITY

RECOMMENDATIONS

- IMPLEMENT TCP/IP ON LAN AS WELL AS DDN
  - TCP/IP IS "KNOWN QUANTITY"
  - SIMPLIFIES GATEWAY
  - PERMITS USE OF PLI's, APPLICATION OF MULITILEVEL SECURITY RESEARCH IN LAN's
  - NO ANALOGOUS INTERNATIONAL/NATIONAL STANDARDS
- PARTICIPATE IN INTERNATIONAL/NATIONAL STANDARDS ACTIVITIES
- SUPPORT RESEARCH
  - MULTILEVEL SECURITY ON LAN's
  - NEW APPLICATIONS PROTOCOLS (E.G., MULTIMEDIA CONFERENCING)
  - TRUE RESOURCE SHARING

Use of
Transmission Control
Protocols/Internet Protocols
(TCP/IP) in Local Area Networks

Background

- Research Project Started in Washington in May 1978

- Project Objectives

  - To Investigate the Use of Local Networks as a Transition Strategy to the Next Generation Worldwide Command and Control Systems (WWMCCS)

- Approach

  - Connect H6000 to LAN
  - Connect Terminals to LAN
  - Connect New Computers to LAN
  - Use Terminals to Access Both the Old and the New Systems

Requirements

- Interconnection Between 100s of Terminals and 10s of Computers
- Terminal-to-Terminal Communications Up to 19.2 Kbps
- Virtualization of Terminal Characteristics
- Inexpensive Terminal Interfaces
- Computer-to-Computer Communication in the Megabit Range
- High Speed Computer Interfaces With Minimal Impact from Networking Software
- Internetworking

Protocol Issues

- TCP/IP is the DoD Long Haul Network Standard
- What Standard Should be Used on the LAN?
- What Kind of Gateway is Required Between LAN and Long-Haul?
- What is the Functionality of the Gateway?
- What Throughput/Performance Can be Attained on the Gateway
- Inboard vs. Outboard LAN Protocols

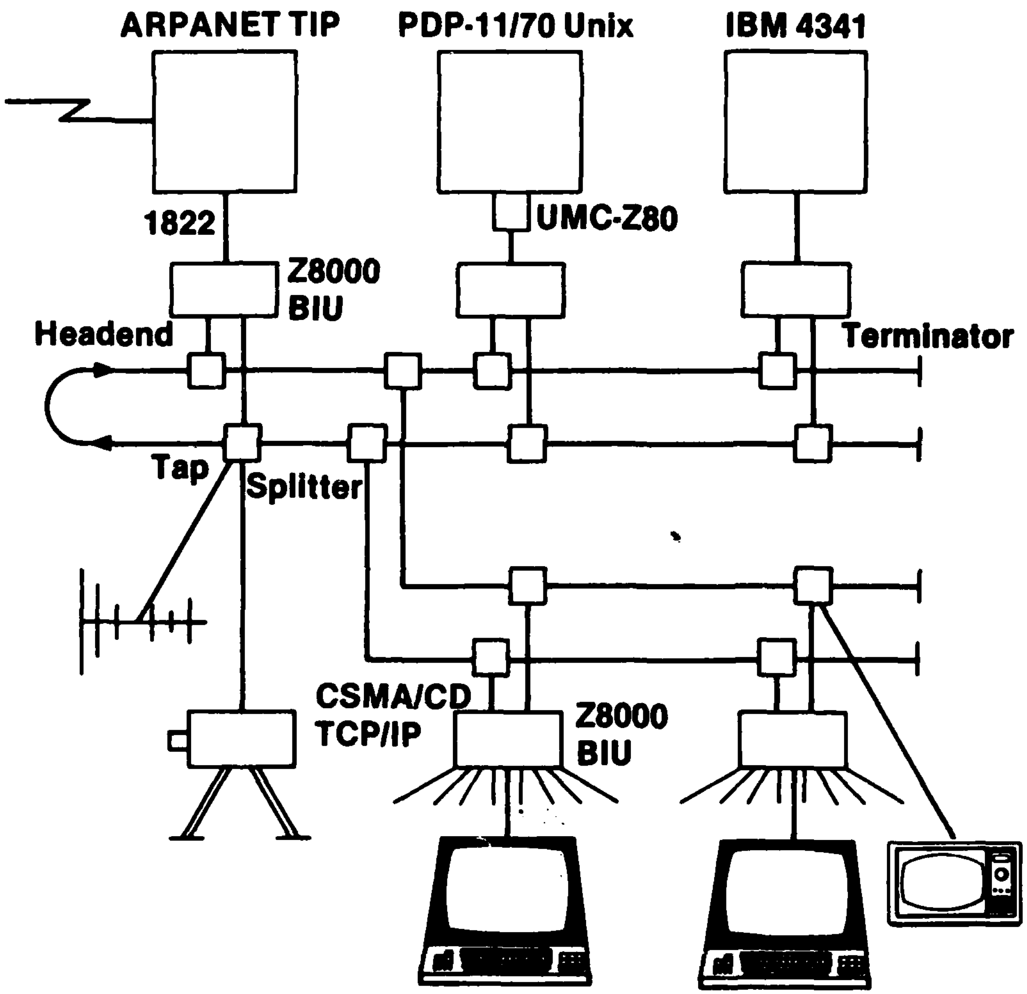
Protocols for Use With Local Networks— The Choice

Layer	International Standards	DoD Standards	Vendor Unique
Application	ECMA Draft File Transfer	ARPANET Mail ARPANET FTP ARPANET Telnet	Vendor Specific
Presentation	CCITT X3/X28/X29		
Session	ISO Draft Std	TCP	
Transport	ISO Draft Std		
Network	CCITT X.25 Packet Level	IP	
Data Link	IEEE 802 Proposed Standard	CSMA/CD or Token	
Physical		Baseband or Broadband	

Approach Investigated

- Outboard TCP/IP
- Low Level Gateway Between LAN and Long-Haul Network
- TCP/IP Implemented in a Z8000 Microprocessor Which Functioned as a Bus Interface Unit (BIU)
- CSMA/CD Used as the Lower Level Protocols
- ARPANET Used to Functionally Simulate the DoD Long-Haul Network

MITRE/Washington Cable Bus Configuration

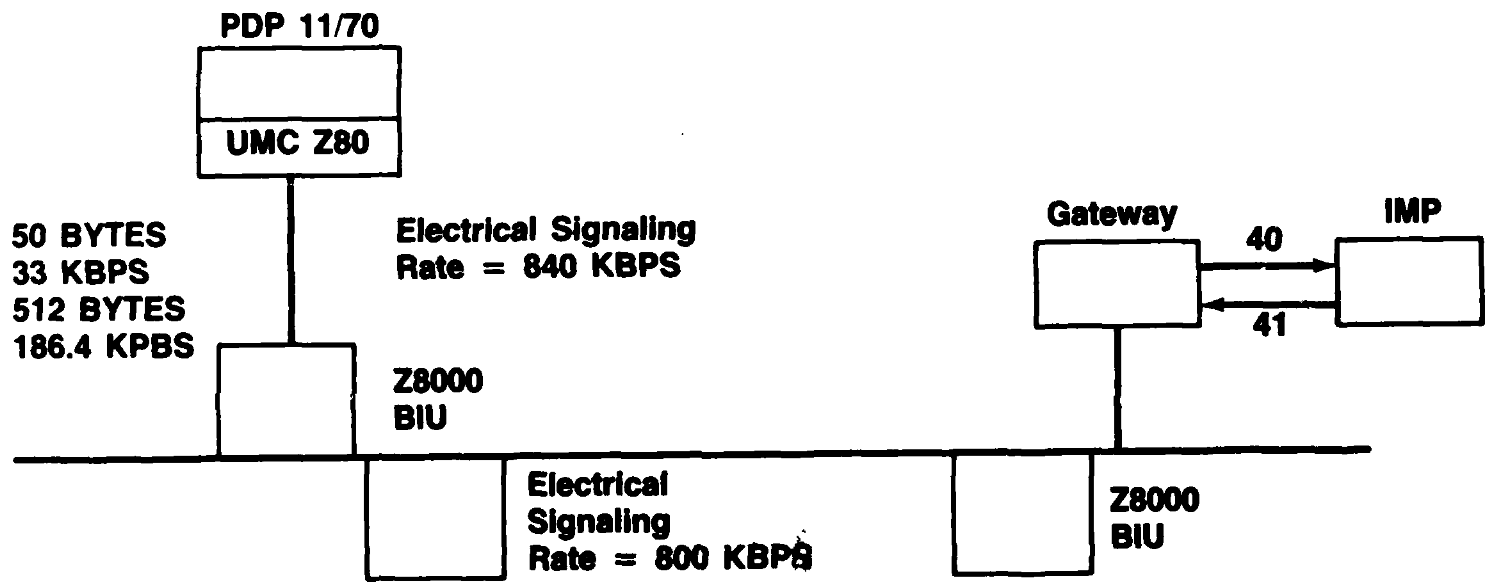


4518

Performance Data

- Electrical Signaling Rate Was 890 KBPS
- Data Flow From Source to Sink Was 350 BITS Per Second With 512 Byte Data Messages
- Limiting Factor Was the S10 Chip Which Was Restricted to 890 KBPS

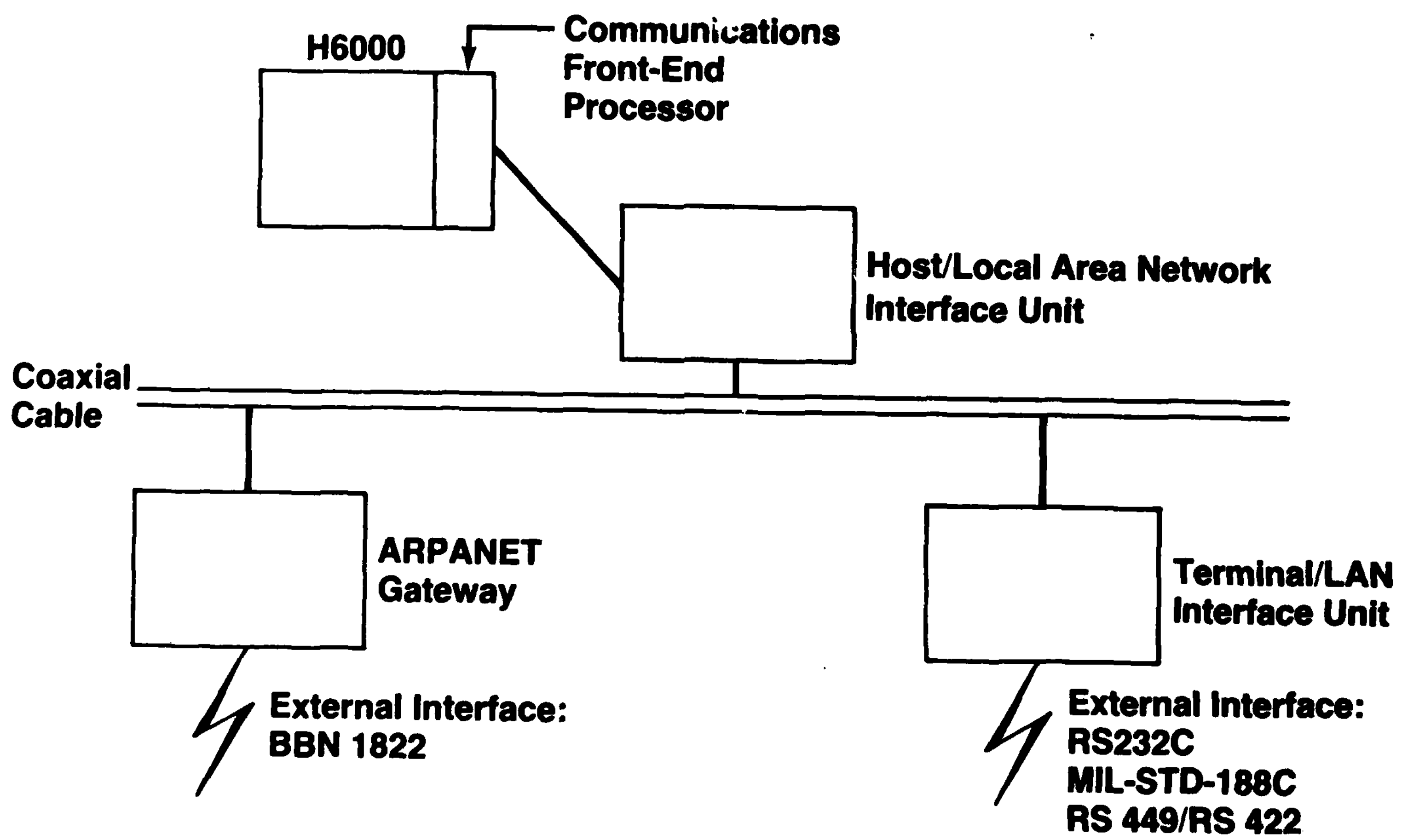
Test Results



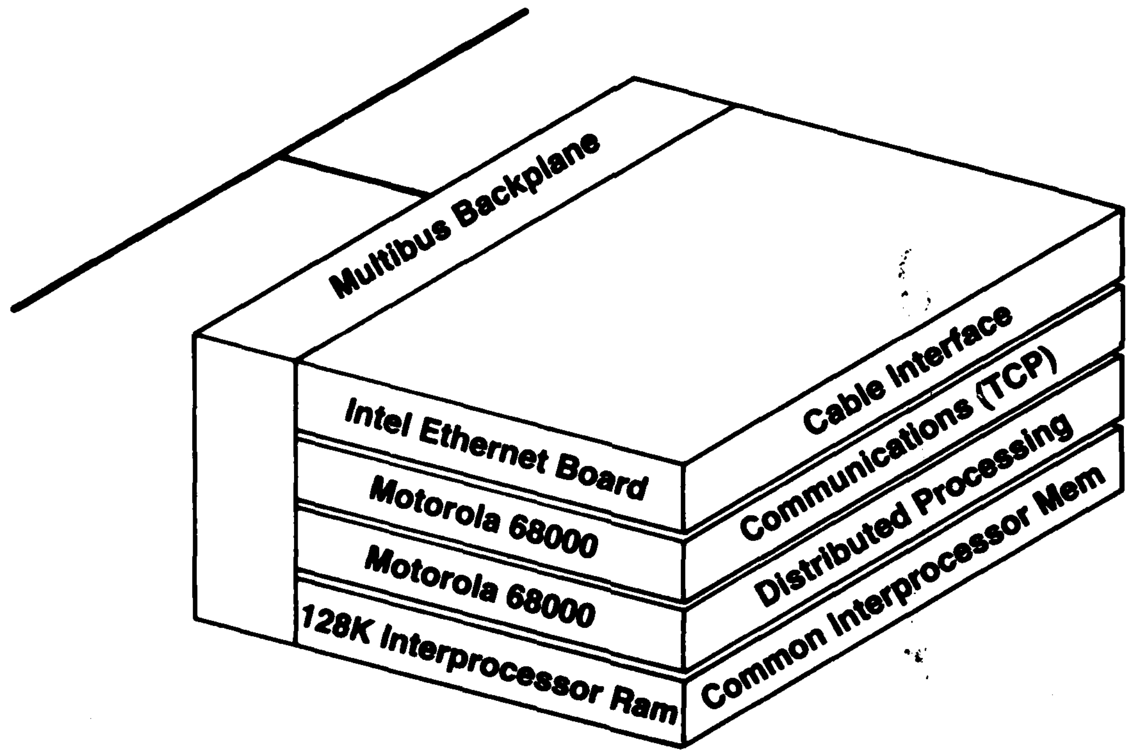
8 BYTE Packets – 200 Packets Per Second – 14.2 KBPS

8 K BYTE Packets – 6.9 Packets Per Second – 452 KBPS

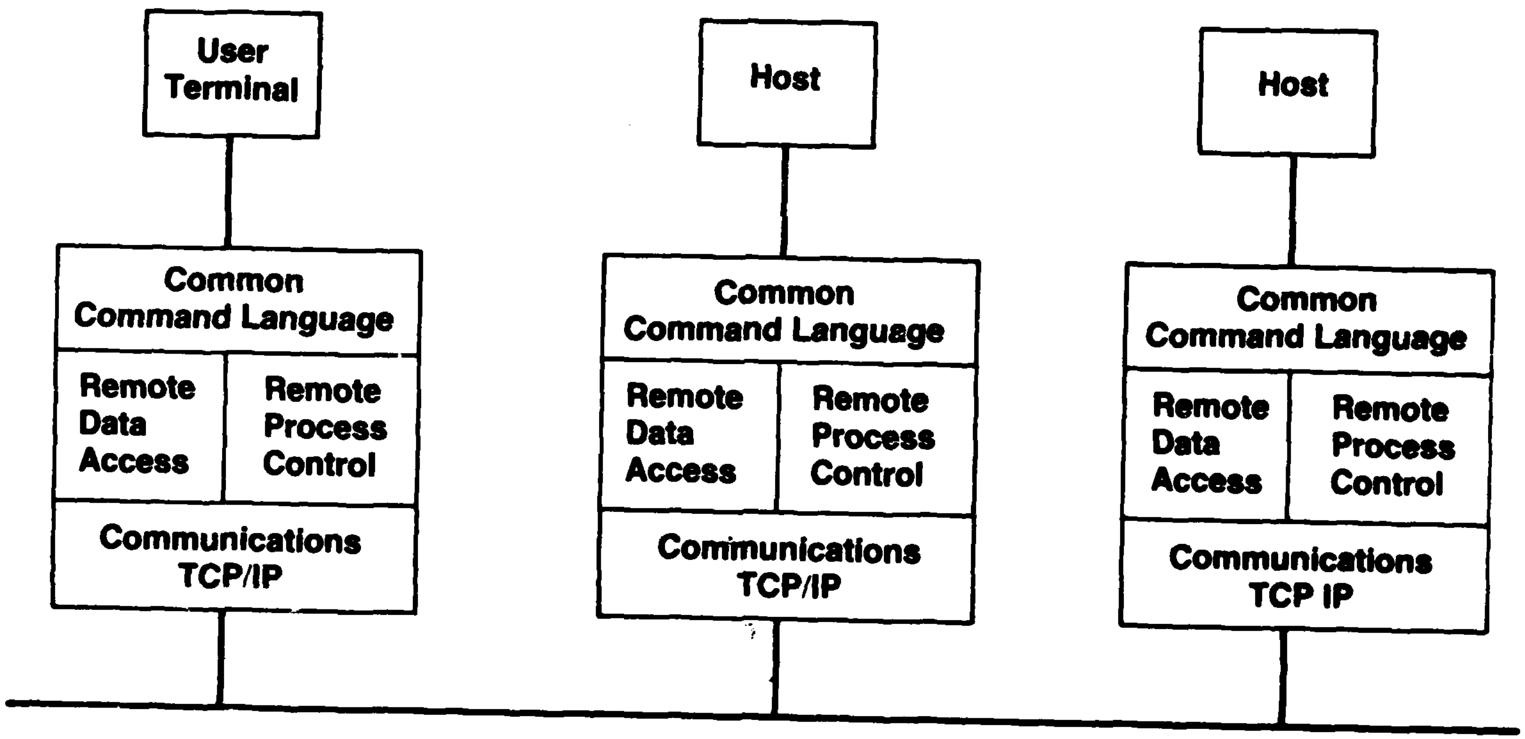
Reston LAN Testbed



Multiprocessor System



Distributed Processing Protocols



Long-Range Goals of Reston Experiments

- Understanding the Distributed Environment
  - Security Issues
  - Performance Issues
  - Protocol Issues
  - Data Base Issues
  - Application Placement Issues
  - Workstation Issues
  - User Interface Issues
  - Internetworking Issues
  - Configuration Management Issues

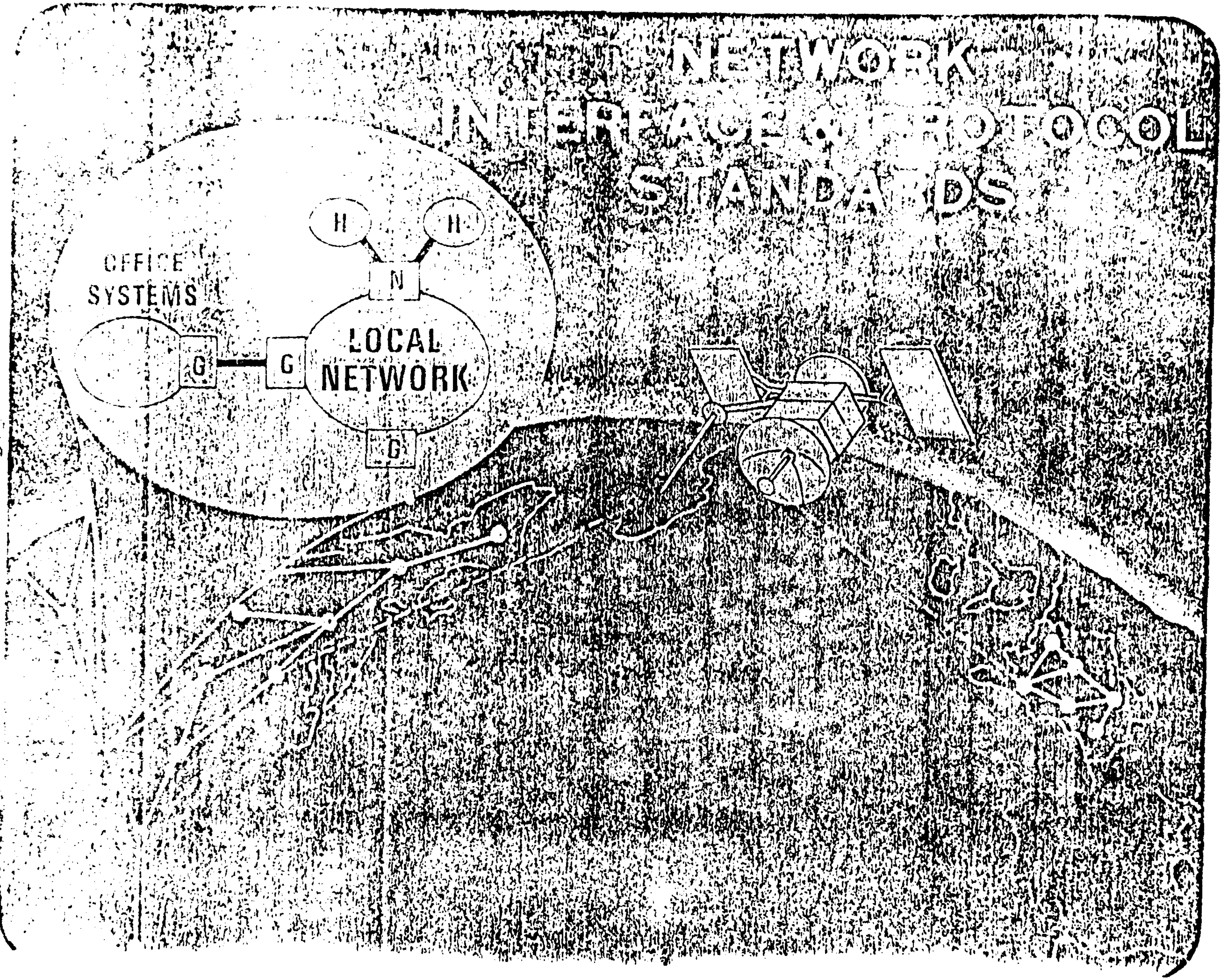
Conclusions

- Performance of TCP/IP Is Good
- Number of Bytes of Overhead Is Not an Important Issue
- TCP/IP Has Built in Security Features Which Can be Exploited for E^3
- 1 MBPS Throughput Is Achievable With the Right Hardware

NATIONAL BUREAU OF STANDARDS

ACTIVITIES IN LOCAL AREA NETWORKS

DAN STOKESBERRY


NETWORK
INTERFACE & PROTOCOL
STANDARDS
OFFICE
SYSTEMS
H
H
N
G
G
LOCAL
NETWORK
G

COMPUTER NETWORK PROTOCOL STANDARDS

OBJECTIVES:

(1) TO MAKE POSSIBLE DISTRIBUTED COMPUTER NETWORKS IN THE FEDERAL GOVERNMENT

(2) TO PROVIDE INTEROPERABILITY AND AVOID UNIQUE, EXPENSIVE SOLUTIONS TO INTEROPERABILITY PROBLEMS

(3) TO ENABLE THE INTERCONNECTION OF DIFFERENT NETWORK COMPONENTS SELECTED ON COST AND PERFORMANCE CONSIDERATIONS

HIGH LEVEL PROTOCOLS

LOCAL AREA NETWORKS

OFFICE AUTOMATION

- ACCESS NEEDS AND IMPACTS
- COORDINATE WITH FEDERAL AGENCIES
- MEET WITH ADVISORY PANELS
- MEET WITH MANUFACTURES
- PARTICIPATE IN STANDARDS ACTIVITIES
- INTERNATIONAL COORDINATION
- U.S. INDUSTRY COORDINATION
- PROVIDE DOCUMENTATION

NETWORK
STANDARDS AND SCHEDULE

<u>1981</u>

MESSAGE FORMAT

<u>1982</u>

TRANSPORT -- BASIC AND EXTENDED
SESSION
FILE TRANSFER AND DATA PRESENTATION
VIRTUAL DEVICE
LOCAL AREA NETWORK
INTERNET

<u>1983</u>

MESSAGE PROTOCOLS
JOB TRANSFER AND MANIPULATION

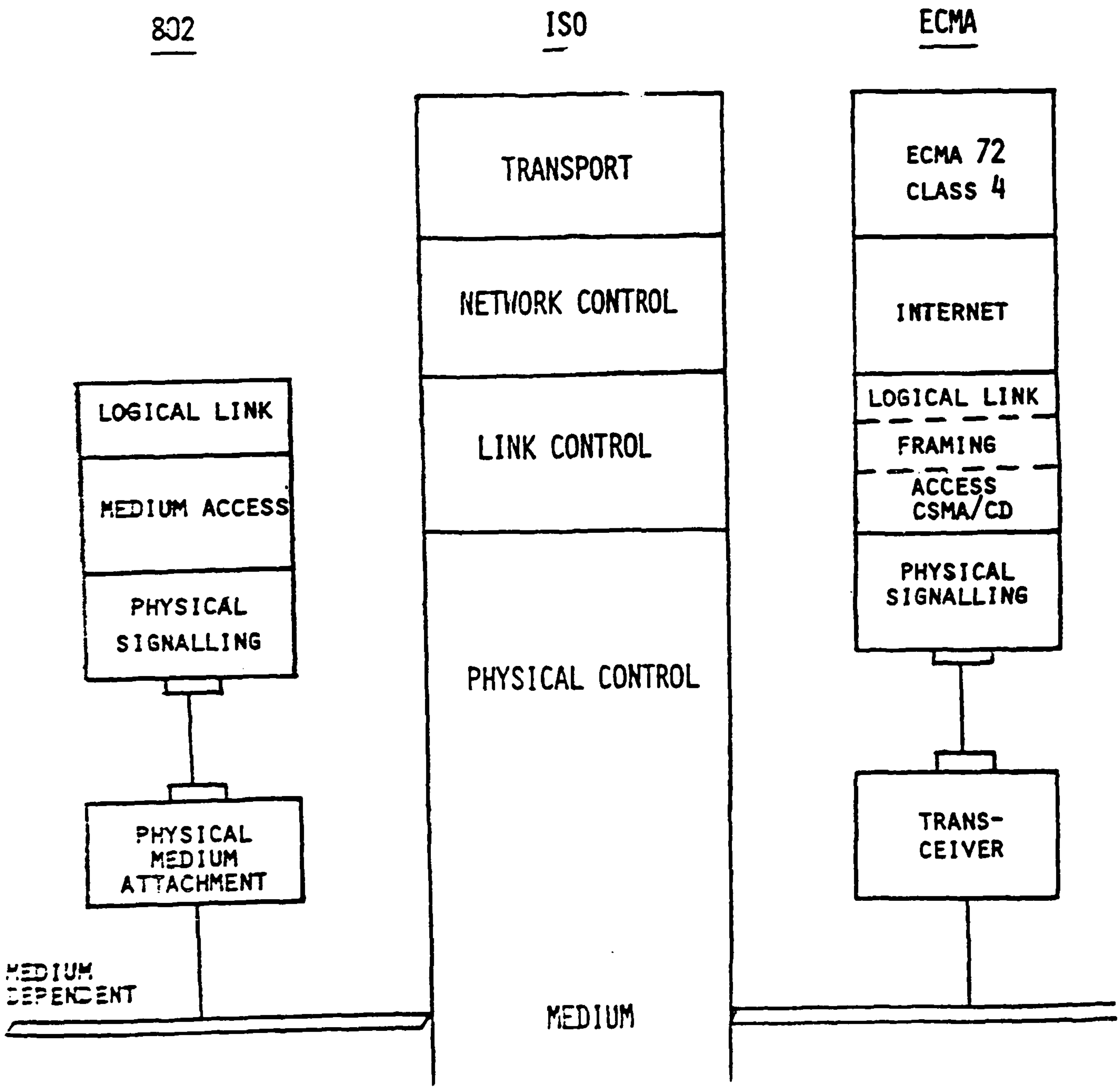
<u>FUTURE</u>

MANAGEMENT PROTOCOLS
DISTRIBUTED DATA PROTOCOLS

STANDARDS ORGANIZATIONS WITH LAN INTERESTS

ISO	TC 97/SC 6
ECMA	TG 24 LN
IEC	PROWAY
ANSI	X3.T9
EIA	TR 40.1
IEEE	802
NBS	FIPS

EVOLVING ARCHITECTURES (JANUARY, 1982)



802 DOCUMENTATION

INTRODUCTION
2/3 SERVICE SPEC
LLC TYPE 1 & 2
LLC/MAC SERVICE SPEC

CSMA/CD MAC	TOKEN BUS MAC	TOKEN RING MAC
1/2 SERV SPEC	1/2 SERV SPEC	1/2 SERV SPEC
PSS/ALL INTERFACE	PSS/ALL INTERFACE	PSS/ALL INTERFACE
BASEBAND COAX MAU	BROADBAND COAX MAU	TWISTED PAIR MAU

SUPPLEMENTARY MATERIAL

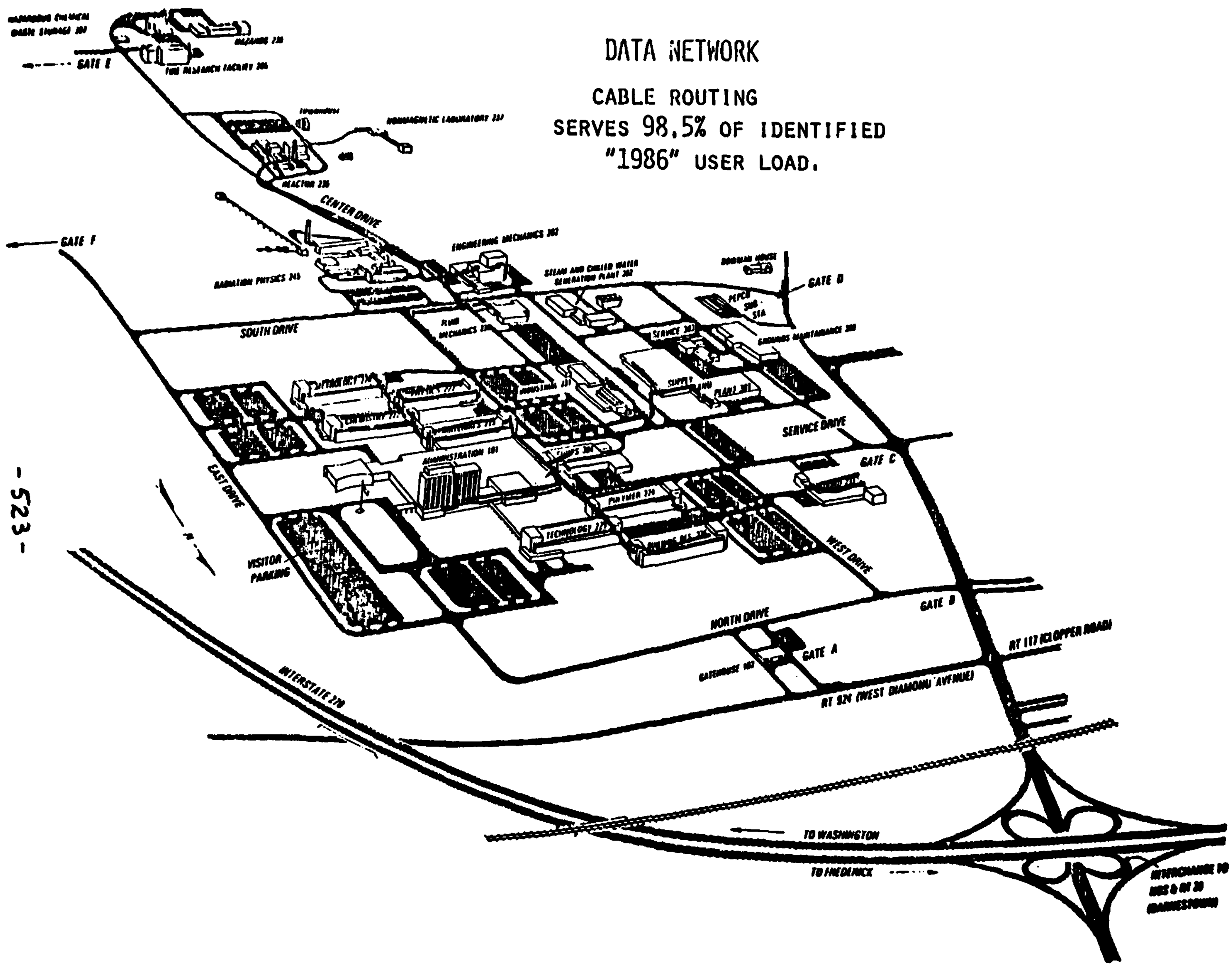
- GLOSSARY
- MANAGEMENT
- INTERNET

FEDERAL INFORMATION PROCESSING STANDARDS

DECEMBER 1982	CSMA/CD	10 MEGABIT BASEBAND
1983	TOKEN RING	
1983	BROADBAND CSMA/CD	
1983	TOKEN BUS	

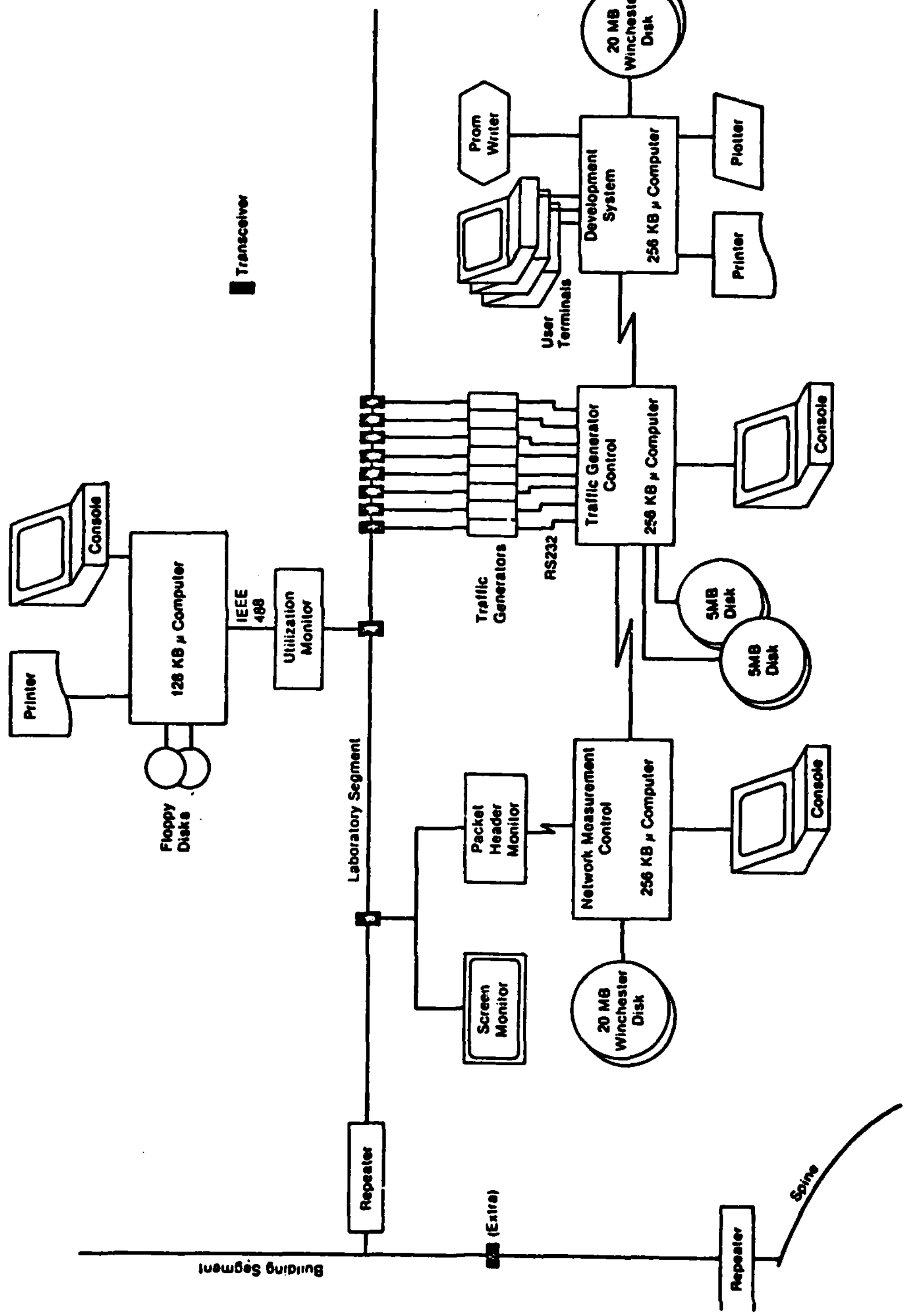
DATA NETWORK

CABLE ROUTING
SERVES 98.5% OF IDENTIFIED
"1986" USER LOAD.

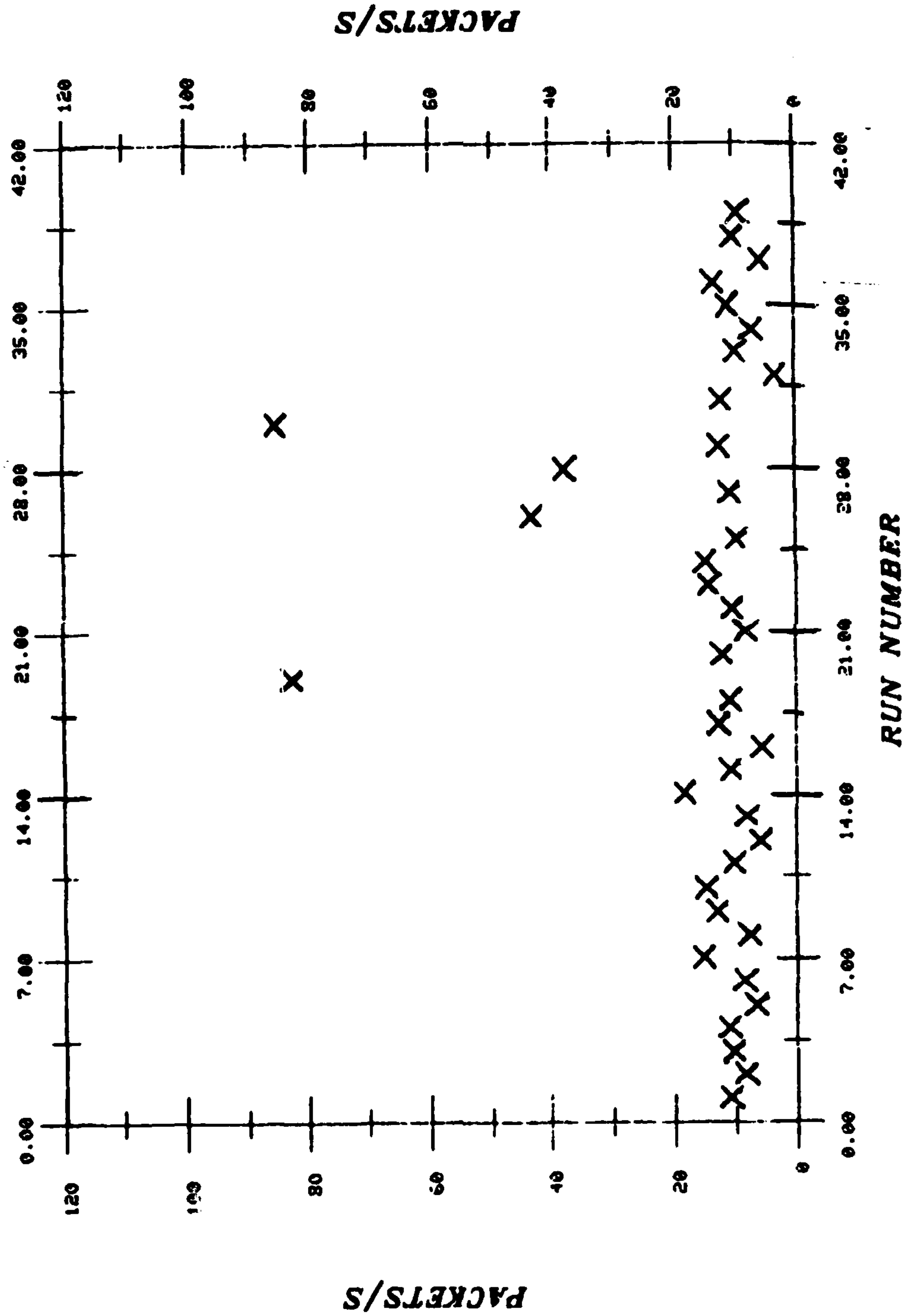


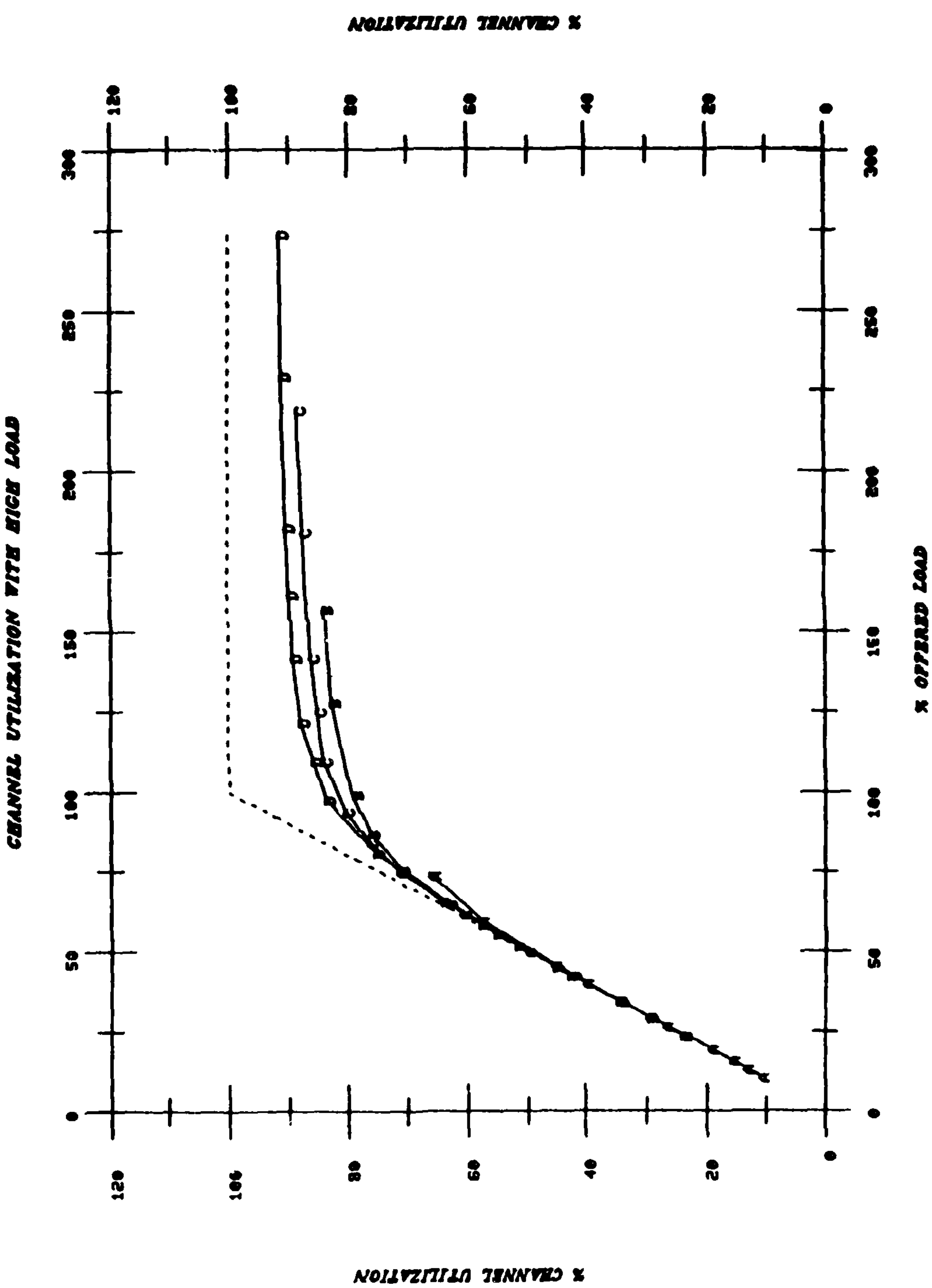
LOCAL NETWORKING LABORATORY

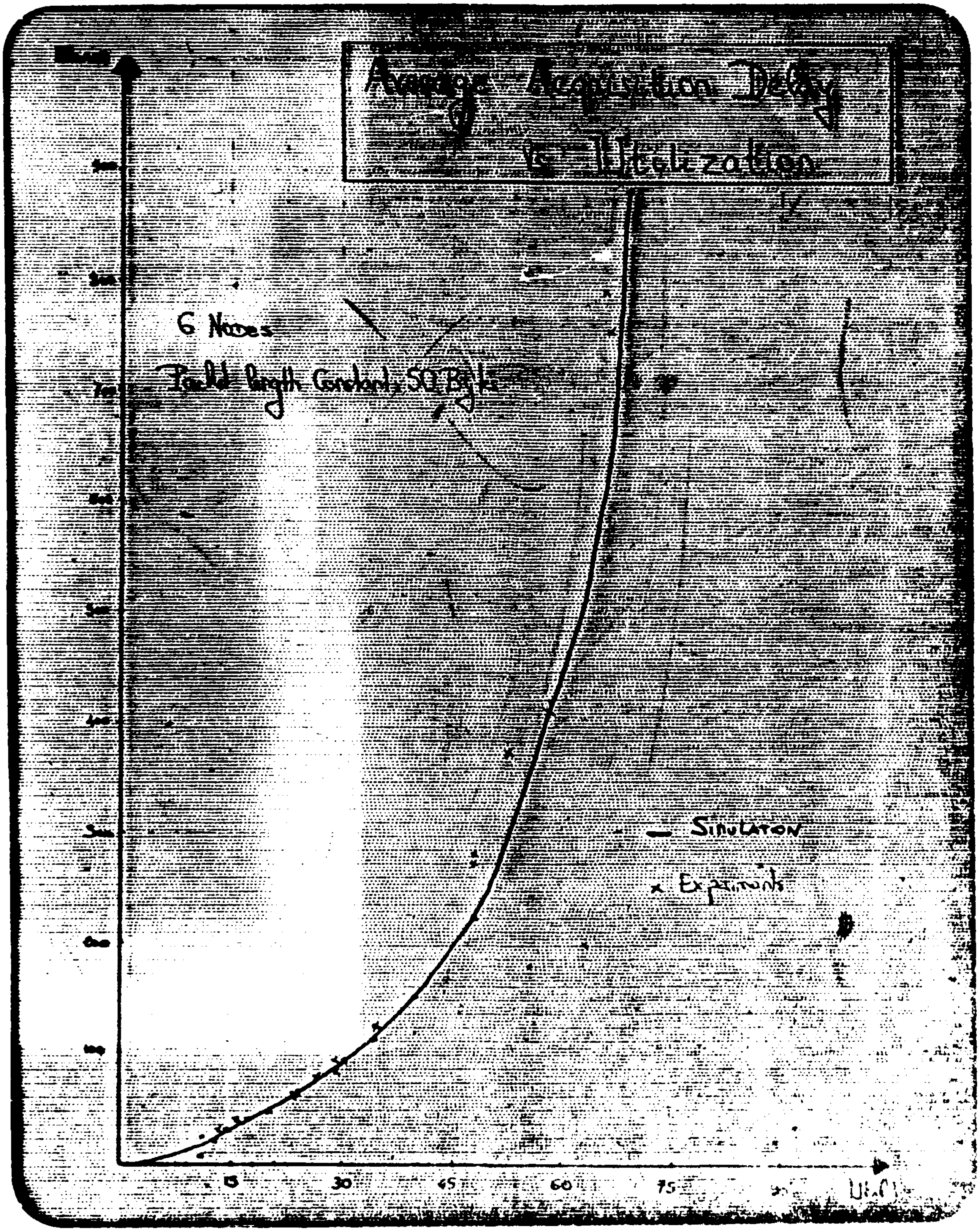
- Performance Measurement
- Traffic Characterization
- Network Management
- Analytic/Simulation Modeling
- Research



Transceiver
Building Segment
(Extra)
Repeater
Repeater
Spine
Laboratory Segment
Screen Monitor
Packet Header Monitor
20 MB Winchester Disk
Network Measurement Control
256 KB μ Computer
Console
Floppy Disks
Printer
128 KB μ Computer
Console
IEEE 488
Utilization Monitor
Traffic Generators
RS232
Traffic Generator Control
256 KB μ Computer
Console
5MB Disk
5MB Disk
User Terminals
Prom Writer
Development System
256 KB μ Computer
20 MB Winchester Disk
Plotter
Printer


PACKETS/S
RUN NUMBER
PACKETS/S
0.00
7.00
14.00
21.00
28.00
35.00
42.00
0
20
40
60
80
100
120


CHANNEL UTILIZATION WITH HIGH LOAD
% OFFERED LOAD
% CHANNEL UTILIZATION
0
50
100
150
200
250
300
0
20
40
60
80
100
120



Average Acquisition Delay
vs Utilization
6 Nodes
Packet length Constant, 50 Bytes
Simulation
x Experiments
15
30
45
60
75

MAJOR POINTS IN PRESENTATION

- NBS Network Protocol Standards Program Includes LANs
- LANs Are Different From Long Haul Networks
- IEEE Is Accredited Under ANSI -- 802 Has LAN Action
- LAN Architectures Are Compatible With OSI Reference Model
- NBS FIPS Include CSMA/CD This Year

Revised 8/24/82
From 2/11/81

CURRENT LIST OF DOCUMENTS AVAILABLE FROM THE SYSTEMS AND NETWORK ARCHITECTURE DIVISION

Address requests to:	National Bureau of Standards Systems & Network Architecture Division B218/Technology Building Washington, D. C. 20234

Federal Computer Network Protocol Standards Program: An Overview

NBSIR 80-2154	The NBS Computer Networking Program
ICST/HLNP-80-1	Features of the Transport and Session Protocols
ICST/HLNP-80-6	Features of the File Transfer Protocol (FTP) and the Data Presentation Protocol (DPP)
ICST/HLNP-80-8	Features of Internetwork Protocol
ICST/HLNP-80-9	Service Specification of the File Transfer Protocol (FTP) and the Data Presentation Protocol (DPP)
ICST/HLNP-80-12	Features of Network Interprocess Communication Protocols
ICST/HLNP-80-15	Service Specification of a Network Interprocess Communications Protocol
ICST/HLNP-81-2	Specification of the Session Protocol
ICST/HLNP-81-6	Specification of the Internet Protocol
ICST/HLNP-81-11	Specification of the Transport Protocol Vol. 1
ICST/HLNP-81-12	Specification of the Transport Protocol Vol. 2
ICST/HLNP-81-13	Specification of the Transport Protocol Vol. 3
ICST/HLNP-81-14	Specification of the Transport Protocol Vol. 4

ICST/HLNP-81-15	An Automated Formal Specification and Implementation Method for Protocols
ICST/HLNP-81-17	The Impact of Satellite Transmission on High-Level Computer Network Protocols
ICST/HLNP-81-18	The Effects of Satellite Technology on the ISO Model of Open Systems Interconnection
ICST/HLNP-81-19	Security in Higher Level Protocols: Approaches, Alternatives and Recommendations
ICST/HLNP-81-20	A Benchmark for Implementions of the NBS Transport Protocol
ICST/HLNP-82-4	Specification of the File Transfer Protocol
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